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CLASS-BOOK

OF

CHEMISTRY.

APPLETON.

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LECTURE OUTLINES—Winter of 1871-2.

No. 2.

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2. Relating to molecules. (*Physics.*)
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   - B. Its sources.
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Prof S. F. Peckham
— from the Author
J C Branner

A

CLASS-BOOK

OF

MODERN CHEMISTRY.

BY

JOHN H. APPLETON, A. M.,

Newport-Rogers Professor of Chemistry in Brown University,
Providence, R. I.

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PREFACE.

THIS little work is printed from the notes to the lectures which the author has delivered to his classes in Brown University.

It is printed for the convenience of future classes in the same Institution.

The author proposes to make it an accessory to lectures, and not a substitute for them.

BROWN UNIVERSITY,
JULY, 1874.

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4th	Series, The Terpenes,	C_nH_{2n-4}.
5th	Series, The Benzenes,	C_nH_{2n-6}.
6th	Series, Phenylene,	C_nH_{2n-8}.
7th	Series, ————,	C_nH_{2n-10}.
8th	Series, Naphthalene,	C_nH_{2n-12}.
9th	Series, ————,	C_nH_{2n-14}.
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BOOK FIRST.

CHAPTER I.

The Branches of Natural Science.

1. There may be as many sciences as there are kinds of subject-matter for scientific treatment.

The Scientific treatment of a subject demands,

(*a.*) exact observation ; (*b.*) precise description with fixed nomenclature ; (*c.*) classified arrangement ; (*d.*) rational explanation.

2. Natural Science, which is the classified knowledge of external nature, may be divided into Natural History and Natural Philosophy.

Natural History includes zoölogy, a history of animals ;
botany, a history of plants ;
geology, a history of the inanimate matter of the earth.

(Coal; fossil skeletons.)

Natural History is ***mainly*** descriptive.

Natural Philosophy includes mechanics, which treats of masses ;
physics, which treats of molecules ;
chemistry, which treats of atoms.

(Alloys.)

Natural Philosophy is ***mainly*** explanatory.

CHAPTER II.

The Constitution of Matter.

Section (A.) The Divisions of Matter.

3. These are, *The atom, the molecule and the mass.*

Atoms.

1st. *An atom* is a unit of matter; in fact, it is the smallest portion of matter that can exist alone. Every atom of matter is viewed as possessing the following characteristics:

It is extremely small.

It possesses weight.

It is indivisible, and indeed in itself unchangeable.

It is endowed with an attractive force called chemical affinity.

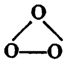
It generally exists in a group, of which the component atoms may be alike or may be unlike. In a few cases an atom may exist alone.

Mercury.
Cadmium.
Zinc.
Barium.

Molecules.

4. 2d. *A molecule* is a group of atoms. When the atoms are of different kinds, the molecule cannot be divided without destroying the identity of the substance. Even when the atoms are of the same kind, the molecule cannot be divided without materially changing the properties of the substance.

Water, H_2O or H—O—H
Antozone, O
Oxygen, O_2 or O=O
Ozone, O_3



Every molecule is viewed as possessing the following characteristics:

It is extremely small, but when in the state of *gas*, it demands the same amount of space as every other molecule in the gaseous state, at the same temperature.

It is not in complete, or absolute contact with its neighboring molecules.

The term molecule is sometimes applied to a single atom, but this use is exceptional; a molecule generally contains two or more atoms.

Protagon, $C_{116}\ H_{291}\ N_4\ P\ O_{22}$
434 atoms.

5. Matter is called *simple* or *elementary*, when its molecules are composed of atoms of the same kind.

$H{-}H \qquad O{=}O$

Matter is called *compound*, when its molecules are made up of different kinds of atoms.

$H{-}O{-}H$ or H_2O

Masses.

6. 3d. A *mass* of matter is made up of a collection of molecules. Any portion of matter appreciable by the senses is a mass.

The Atomic Theory.

7. These views of the constitution of matter are founded, though with very considerable modifications, upon the Atomic theory of Dr. John Dalton, who began to develop his theory in 1803.

In some ancient metaphysical speculations, matter was held to be infinitely divisible, while in others the contrary view was maintained.

The modern chemist declares that in fact, there is a limit to its divisibility.

Modern views of the constitution of matter are based upon several important laws, which experiment, and particularly the use of the balance, has shown to govern chemical action.

The Law of Definite Proportions.

8. *The same compound, always contains the same elements united in the same proportions, and with the same molecular arrangement.*

Thus, Water, H—O—H consists of
H_2 — 2 parts by weight.
O — 16 “ “
18

and Hydrogen peroxide, H_2O_2 or H—O—O—H consists of
H_2 — 2 parts by weight.
O_2 — 32 “ “
34

and Hydric Sulphide, H_2S or H—S—H consists of
H_2 — 2 parts by weight.
S — 32 ,, ,,
34

The Law of Multiple Proportions.

9. *When the element A, unites with the element B, in more than one proportion, they form more than one compound; and the several amounts of B combined with the same amount of A bear a very simple relation to each other.*

A B	N_2O
A B_2	N O or N_2O_2
A B_3	N_2O_3
A B_4	N O_2 or N_2O_4
A B_5 etc.	N_2O_5

Gay Lussac's Laws.

10. *When two or more gases combine, the volumes of the gases so combining, bear very simple ratios to each other.*

When two or more gases combine to form a product which can remain a gas, the volume of the compound gas bears a very simple ratio to the sum of the volumes of the component gases.

11. The smallest volume of a gaseous element that can enter into combination may be called its combining volume.

The combining volumes of all elementary gases are equal [excepting those of Phosphorus and Sulphur, which are only one half of those of the other elements in the gaseous state; and also excepting those of Mercury and Cadmium, which are probably double those of the other elements.]

Boyle's and Mariotte's Law.

12. *The volume of every gas when confined, is inversely proportional to the pressure to which it is exposed.*

Charles' Law.

13. The co-efficient of expansion of gases is the same for all of them, *i. e.*, .003665 or $\frac{1}{273}$ for 1° Centigrade; now, if we adopt—273° C. as 0° of absolute temperature, and then consider 0° C. to be + 273° of absolute temperature, then the law may be stated thus:

"*The volume of a given mass of gas, under a constant pressure, varies directly as the temperature, expressed in absolute Centigrade degrees.*"

Avogadro's and Ampère's Law.

14. *Equal volumes of all substances, when in the gaseous state, and under like conditions of temperature., pressure, &c., contain the same number of molecules.*

Section (B) The Attractions of Matter.

1st. The Attractions of Masses.

15. Gravitation is a force, by which portions of matter are mutually attracted, whatever their *size, distance apart, or the intervening medium.*

16. *Law. The attraction between material objects is directly proportional to their masses, and inversely proportional to the squares of the distances between their centres of gravity.*

17. In case of any two material objects:

1st. If without other alteration, the mass of one be doubled or trebled, &c., the mutual attraction will be doubled and trebled, &c.

2d. If without other alteration, the mass of one be doubled, and simultaneously the mass of the other be trebled, &c., the mutual attraction will be increased six, &c., times.

3d. If without other alteration, the distance between the centres of gravity be increased from one unit, to two, three, four units, &c., the attraction will be *diminished* to the 4th, 9th, 16th part &c., of its former intensity.

18. *Value.* Gravity is the great agent of stability in nature.

It regulates the motions of the heavenly bodies.

It is by its influence that objects on the surface of the earth retain their position and are not thrown off into space.

Its value is best estimated when we consider the results which would follow its suspension.

2d. The Attractions of Molecules.

Cohesion.

19. Cohesion is the attractive force, acting at insensible distances between molecules of the same kind.

Besides the cohesive force, molecules of the same kind are sometimes influenced by a repulsive force.

20. In *solids*, the cohesive force manifests itself in the resistance they offer to any derangement of shape, *i. e.*, of the arrangement of molecules in the mass. This resistance may oppose itself to

1. Linear extension.
2. Linear compression.
3. Cubical compression.
4. Torsion.
5. Flexure.

21. In *gases* we find the opposite extreme. They seem to possess little or no cohesive force; the repulsive force predominates. A few cubic inches of gas placed in an empty receiver, of any shape, and of any size (not exceeding forty or fifty miles in height), would doubtless soon expand, so as to fill the receiver. It is to this repulsive force that the elasticity or tension (*i. e.*, the expansive tendency) of gases is due.

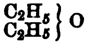
It is probably the remoteness of the molecules of a gas from one another that removes them from the influence of cohesion, This same consideration makes the gaseous condition of matter, one of peculiar interest and usefulness in the investigations of molecular physics.

22. *Liquids* present to us conditions, intermediate between those of solids and of gases.

Liquids manifest cohesion in their tendency to assume the globular form, (that affording the most compact arrangement for a given number of objects).

Liquids display the existence of the repulsive force in their tendency to evaporation.

Ethylic Ether



$\left.\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right\}O$

Mercury

23. *Polarity.* There is a striking difference between the adjustment of the molecular forces in solids and in liquids. In liquids the cohesive forces seem to be balanced about the centres of the molecules, so that they are free to move upon each other, and to occupy equally well, many positions with respect to each other. In solids, on the other hand, the cohesive force seems to reside out of the centres of the molecules, and in certain centres of force which may be called poles.

Crystallization.

24. This polarity not only compels solids to offer the resistance to derangement of shape already referred to. It also produces the phenomena of Crystallization.

With the exception of a few animal and vegetable products, every solid affects a definite polyhedral form, although it may manifest this tendency only under favorable circumstances.

Bodies possessing such forms are called crystals.

The *axes of a crystal* are lines of direction passing through the centre of the crystal, and joining opposite and corresponding sides, edges, or angles. One axis is usually adopted as the vertical or principal axis,—the others are called secondary axes.

25. *Simple forms.* When a crystal is bounded by faces that are geometrically similar to each other, it is called a *simple crystal*; a *compound crystal* is bounded by dissimilar faces.

If in a compound form, one series of similar sides be conceived to be extended so as to completely hide the others, a *simple form* is the result. It thus appears that a given compound form is a combination of as many simple forms as there are different kinds of faces in the compound form; but it must not be forgotten that in a given crystal, only forms of the same system are met with.

Generally, one set of the faces of a compound crystal is developed more than the others: such set belongs to what is then called the *dominant* form, while the others belong to what are then called *secondary* forms.

26. Many crystals possess *cleavage* to a striking degree Cleavage is the property by virtue of which crystals may be split in certain planes, with far greater ease than in others

Crystals are usually *formed*

(*a*) by the slow cooling of vapours.

(*b*) by the slow cooling of liquids produced by solution.

(*c*) by the slow cooling of liquids produced by fusion.

The action of *slow cooling* depends upon the facts that heating weakens the force of cohesion, and that slow cooling favors its *gradual* action, and so affords time and opportunity for that symmetrical arrangement of molecules which gives rise to crystals.

27. Although the varieties of crystals known in nature

and in the arts are very numerous, yet all of them may be classified in six systems, *i. e.*, all of them may be shown to be derived from six primary forms.

1st System.—The Monometric.

28. The forms of this system are characterized by 3 axes; all are inclined at right angles to each other; and all are of equal length.

The cube.
The regular octahedron.

2d System.—The Dimetric.

29. The forms of this system are characterized by 3 axes; all are at right angles to each other; 2 are of equal and the 3d of different length.

The square prism.
The square octahedron.

3d System.—The Hexagonal.

30. The forms of this system have 4 axes; 3 are in the same plane and are separated by equal angles, (that is, by angles of 60 degrees,) and are of equal length. The 4th axis is perpendicular to the plane of the other 3, and is of different length from them.

The hexagonal double pyramid.
The hexagonal prism.

4th System.—The Trimetric.

31. The forms of this system have 3 axes; all are at right angles to each other; all are of different lengths.

The rectangular prism.
The rectangular octahedron.

5th System.—The Monoclinic.

32. The forms of this system have 3 axes; two are oblique to each other; the 3d is perpendicular to the plane of the other 2; all 3 axes are of different lengths.

This system does not include any *simple forms*, and its crystals have only a sort of bilateral symmetry.

6th System.—The Triclinic.

33. The forms of this system have 3 axes; all are oblique to each other; all are of different lengths.

This system does not include any *simple* forms; its crystals can scarcely be said to have symmetry; it includes comparatively few substances.

Adhesion.

34. Adhesion is the attractive force, exerted at insensible distances, between molecules of different kinds.

(A) Adhesion between Solids and Solids.

Granite.
Cements.

(B) Adhesion between Solids and Liquids.

35. I. Moistening.

A glass rod dipped in water.
A zinc rod dipped in mercury.

II. Capillary attraction.

36. When a tube open at both ends, is dipped into a larger vessel containing a liquid, there may be three cases:

First case. If the adhesion between the liquid and the solid composing the tube, be *less than one half the cohesion* between the molecules of the liquid itself, then the surface of the liquid in the tube will form a convex meniscus, and it will be lower than the general level of the liquid in the vessel.

(Mercury in a glass tube.)

Second case. If the adhesion be *equal to one half the cohesion*, then the liquid will have a plane surface, and it will be on the same level as the general surface of the liquid in the vessel.

Third case. If the adhesion be *greater than one half the* cohesion, then the surface of the liquid in the tube will form a concave meniscus, and it will be above the level of the general surface of the liquid in the vessel.

III. The Spheroidal State.

37. When a portion of liquid is dropped upon the surface of a level solid, the form assumed by the liquid depends upon the relative intensities of (*a*) *cohesion in the liquid*, ; (*b*) *adhesion between the solid and liquid*; and (*c*) *gravitation.*

First case. The one extreme case is when the adhesion is *less than twice the cohesion*, the mass of the liquid being at the same time small. The liquid now draws itself up into a spheroid, and is said to be in the spheroidal state. When the solid is highly heated, the adhesion may be so reduced as to afford the conditions demanded by this case. The globule is then assisted to maintain the spheroidal condition, by the cushion of vapour constantly forming on its under side by the heat *radiated* from the hot solid.

Second case. The other extreme case is when the adhesion is *greater than twice* the cohesion, especially when the amount of liquid is large. The liquid now spreads itself over the surface and wets it.

IV. Solution.

38. When the adhesion of a liquid to a solid, entirely overcomes the force of cohesion in the solid, the latter is said to enter into solution.

Solvent power varies with the nature of the substances and with the temperature. It is generally the greater, the greater the similarity of solid and solvent. It is generally the greater the higher the temperature.

(C) Adhesion between Solids and Gases.

39. A solid, when immersed in a gas and then withdrawn,

retains a thin film of gas upon its surface, somewhat as a solid is wetted by dipping in water.

Some solids condense, in this way, a bulk of gas within their pores, such that the gas is occupying a less volume than it would occupy if condensed to the liquid state by itself.

The metal Palladium is remarkable for absorbing or *occluding* at ordinary temperatures, 800 times its bulk of Hydrogen gas. The late Professor Graham of London, who observed this property of Palladium, considered the solid thus formed to be an alloy, and to contain Hydrogen in the solid form.

(An alloy is the solidified solution of one metal in another. The properties of alloys such as color, melting point, &c. are rarely the means of the properties of their components when unmixed.)

The metal Platinum has the same power as Palladium, though to a less degree. When in the form of Platinum-black it absorbs 250 volumes of Oxygen.

(D) Adhesion between Liquids and Liquids.

40. In general, the adhesion of liquids to liquids, so far exceeds their respective cohesive forces, that the liquids may be mixed in all proportions.

In general, heat favors this sort of diffusion.

Example. **Water and Sulphate of Indigo.**
Exception. **Water, Oil and Mercury.**

Osmose of liquids. In case of two liquids separated by a porous septum, (it being granted that there exists adhesion between the liquids, and a difference in the amounts of adhesion of the two liquids for the septum,) then the liquid which wets the septum the better, passes through the more rapidly.

(E) Adhesion between Liquids and Gases.

41. Water has the power of dissolving all gases, though in very different proportions.

Law. The amount of gas, absorbed by a liquid upon which it exerts no chemical action, depends upon

i. the nature of the gas and liquid ;

ii. the pressure to which they are exposed ; (the amount of gas absorbed varies directly as the pressure)

iii. the temperature; (with few exceptions, the solubility of a gas in a liquid is greater, the lower the temperature)

(but water, on freezing, expels its dissolved air; and molten silver, on solidifying, expels the twenty volumes of Oxygen dissolved by it.)

(F) Adhesion between Gases and Gases.

42. The tendency of gases to mix with each other is so strong that it will overcome the greatest differences of specific gravity; and the lighter the gas, the greater the rapidity with which it distributes itself among the molecules of an adjacent gas.

The atmosphere of our globe affords a splendid example of gaseous diffusion.

1st Because it consists of a mixture of one-fifth Oxygen and four-fifths Nitrogen, by bulk. Now, though the density of Oxygen is 16 while that of Nitrogen is but 14, the former does not settle out, but remains thoroughly intermixed with the other.

2dly Because both the respiration of animals and the burning of fuel are constantly casting into the atmosphere, immense quantities of Carbonic anhydride gas. This gas has the density 22.

Thus,	
formula	CO_2
atomic wt. of C	12
twice the atomic wt. of O	32
molecular wt. of CO_2	44
density of CO_2 *one-half its molecular wt.*	22.

It is thence much heavier than the air, whose density is 14.4 nearly.

Thus,	*one volume of O*	16
	four volumes of N, 4×14	56
	five volumes of air,	72
	one volume of air,	14.4

It however quickly mixes with the air by diffusion.

43. But this tendency of gases to intermingle, is not due to adhesion solely. The molecules of all matter, even the most rigid, are believed to be in active motion within the mass. But the molecules of the gaseous form of matter are almost uninfluenced by cohesion. Hence they *manifest* this internal molecular motion to the most striking degree.

There are four forms of gaseous motion that deserve attention. By the first two, gases move as *masses;* by the second two they move as *molecules.*

They are, 1st. Effusion and Transpiration.
2d. Diffusion and Osmose.

44. *Effusion.* When a mass of gas is allowed to flow into a vacuum, it does so very rapidly. If the case is that of a mixture of two or more gases, they all pour into the vacuum in quantities proportional to those in which they existed in the original mixture. The gases are forced into the vacuum mainly by the pressure of our atmosphere. This pressure is caused by gravitation. The flow of the gas is governed by the same law that governs the fall of a heavy body to the earth. (The rates are inversely as the square roots of the densities of the gases.)

The truth of the law has been demonstrated by Professor Graham, by allowing gases to flow into a sustained vacuum, through a perforation in a very thin platinum plate, the perforation being somewhat less than one-three-hundredth of an inch in diameter.

45. *Transpiration.* When the perforated plate has a considerable thickness (say one-fourth of an inch) the perforation

has become practically a capillary tube. The gas, or mixture of gases, in passing through such a tube experiences a resistance similar to that of friction.

The law of the flow eventually becomes constant, when the tubes attain a length equal to four thousand times their diameter. It involves temperature, pressure, diameter and length of tube, but not its material. But it is independent of density or of any known property of gases. If a mixture of gases be experimented upon, they pass through, still mixed.

46. *Diffusion.* In Effusion and Transpiration, gases move in the form of the mass and they move through apertures or capillary tubes. But if the apertures or capillaries be very much diminished in size, the gas no longer moves in the form of the mass. It moves in the form of the molecule. This is readily proved by the fact that by *diffusion*, a mixture of gases is separated into its constituent gases. The molecules of the lighter gas pass very quickly through the extremely fine capillaries. The molecules of the heavier gas pass through very slowly. Diffusion is well performed through a thin diaphragm of compressed graphite, or of plaster-of-paris, or of porous, but fine grained earthen ware.

The operation is illustrated by the Diffusiometer.
Its construction.
Its action.

Law. The relative diffusion-rates of two gases are inversely as the square roots of their densities.

Now the diffusion-rate of Oxygen has been learned by experiment; so has that of Hydrogen. They are, as 1 for Oxygen to 4 for Hydrogen.

But their densities have also been learned by experiment: they are as 16 for Oxygen to 1 for Hydrogen. In other words:

$$\begin{matrix}\textbf{Diff. rate} \\ \textbf{Of H}\end{matrix} : \begin{matrix}\textbf{Diff. rate} \\ \textbf{Of O}\end{matrix} :: 4 : 1 \text{ or } :: \sqrt{16} : \sqrt{1}$$

47. *The explanation of diffusion.* This is based upon the facts already stated, together with one or two others.

The molecules of matter are believed to be in a state of rapid vibration, but at velocities varying with the different kinds of matter.

If a gas be confined in a porous vessel (e. g. in the cell of a diffusiometer) then the gas is projected, by the molecular motion, into the open passages of the earthern ware, and passes through and out. Simultaneously, and in the same manner, the external gas is carried inwards, but the rate of passage is different in different gases. But the molecules of the lighter gas pass through more rapidly, because they are always moving with greater rapidity.

48. *This view of diffusion accords with the laws of mechanics,* for we may *suppose* two rubber balloons of exactly the same size and of exactly the same thickness of rubber, but the one containing Oxygen and the other containing Hydrogen.

The compressing influences are by the above suppositions, the same in the cases of both balloons. These influences are first, the contractile force of the same amount of india-rubber, and secondly, the atmospheric pressure.

The expansive influences are the same in both cases, for otherwise the balloons would be of different sizes. These influences are respectively the tension of the Oxygen and the Hydrogen gases.

This tension is maintained by the outward impact of the Hydrogen molecules in the one case, and by the outward impact of the Oxygen molecules in the other case. Moreover the numbers of molecules are the same in both cases, for by Ampère's law, we admit that equal bulks of gases contain equal numbers of molecules.

Let i represent the impact of Hydrogen,
and I the impact of Oxygen,

$M =$ mass of Oxygen molecule $= 16$

$V =$ velocity of Oxygen molecule, temporarily adopted as the standard of comparison $= 1$

m = mass of Hydrogen molecule = 1
v = velocity of Hydrogen molecule = factor sought.

now, $$i = I \qquad [1]$$

but since impact is equal to one-half of mass into the square of velocity, we have

$$i = \frac{1}{2} mv^2 \qquad [2]$$

$$\text{and} \quad I = \frac{1}{2} MV^2 \qquad [3]$$

$$mv^2 = MV^2 \qquad [4]$$

$$\therefore v^2 = \frac{MV^2}{m} = \frac{16 \times 1^2}{1} = 16 \qquad [5]$$

$$v = \sqrt{16} = 4 \qquad [6]$$

This last equation means that the velocity of the Hydrogen molecule is four times that of the Oxygen molecule. In other words, the laws of mechanics help to substantiate both Ampère's law and the views of the real meaning of diffusion, as they have been already presented.

49. *Osmose.* This term is applied to the passage of gases through *membranous* diaphragms such as caoutchouc, bladder, etc. The rate of interchange varies with the relative diffusibilities of the gases, and the porosity of the membranes, as well as with the different degrees of adhesion which the membranes exert upon the different gases.

The gas which adheres to the diaphragm most powerfully, penetrates it best.

If the membrane is *moist*, the result is likewise affected by the degrees of solubility of the gases, in the moistening liquid.

3d. The Attractions of Atoms.

50. Chemical affinity is an attractive force, acting at insensible distances between the atoms of matter.

(*a*.) Within its own limits, it acts with intense energy, but beyond those limits it is utterly powerless.

But certain physical agencies help either to bring substances within the range of chemical affinity, or to drive them beyond it.

Solution,	Seidlitz powders.
Heat,	coal and oxygen.
Light,	vegetable growth; photography.
Electricity,	decomposes silver solutions in electro-plating.

(*b*.) It is exerted between different substances with different but definite degrees of force.

Gold and Iron oxydize with different degrees of ease; but it is always the Iron that oxydizes the easier.

(*c*.) *The law of insolubility.* When there are present in a solution, elements which can form an insoluble compound, that compound will generally be formed, and will appear as a precipitate.

(*d*.) *The law of volatility.* When there exist in solution, substances whose reaction can produce a gas or a substance volatile at the temperature of the experiment, such volatile product will generally be formed and liberated.

(*e*.) The amounts of the *ponderable substances* taking part in a reaction are definite; and the products are equal in weight to the factors.

(*f*.) The amount of *energy* involved in chemical reactions is definite; when the elements of a compound are drawn apart, the energy *required* to effect such a separation is exactly the same as the energy *evolved* in the act of union of the elements in question.

Light and heat are manifestations of energy which often attend chemical union.

(*g.*) As its sphere of action is within the molecule, it always produces changes of *identity*, and so gives rise to most marked and unexpected changes in the substances affected by it.

Section (C.) The Movements of Matter.

1st. The Movements of Masses.

This subject belongs to Mechanics.

2d. The Movements of Molecules.

51. The motions of the molecule within the mass, have received different names according to their character, e. g. Heat, Electricity, etc.

Although these subjects properly belong to the department of Physics, yet Heat, by its sources, uses, and effects, is so closely associated with chemistry, that a few words about it, are not out of place here.

Heat.

52. The invisible agency by which our sensations of warmth and of cold are produced, is itself called heat. We distinguish two kinds of heat.

i. *Absorbed heat* is that which resides in a hot body, often remaining in it for a considerable time. It is transferred to another body, mainly by contact.

ii. *Radiant heat* is heat in the act of passing, with great velocity, through space whether vacuous or otherwise; it may be either dark heat or luminous heat (the latter form being commonly called light).

Velocity, about 186,000 miles per second.

(*a*) *Theories of its Nature.*

53. The Dynamical theory, that now generally accepted,

supposes that all matter as well as all space is pervaded by an extremely delicate and elastic medium called the *ether*. This theory regards

(i.) Absorbed heat as a vibration of the molecules of matter.
(ii.) Radiant heat as an undulatory movement in the ether.

Under proper conditions, the one form may be changed into the other, without loss of energy; for this theory adopts the view called the *Conservation of force*. This theory is that it is impossible for us to create or to destroy *energy*, just as it is impossible for us to create or to destroy *matter*. We can only change the form, which the force or the matter assumes.

(*b*) *Its Sources.*

54. These are Friction, Percussion, Chemical action and the Sun.

Of chemical action, we may remark that it is the great source of man's artificial heat.

The Sun is ultimately the source of all our heat and energy, (except, perhaps, that of the tidal wave).

It affords us heat *directly* by radiation;
Indirectly, by stimulating vegetable growth, it affords us food and fuel.

(*c*) *Its Effects.*

i. Temperature.

55. This is merely the condition of a body with respect to *sensible heat*. It gives us only an idea of the relative amount of heat given out by a body, as compared with the heat given out by our own persons, but gives us no idea of the absolute amount of heat in the body in question.

ii. Expansion.

56. In general, by addition of heat, solids, liquids and gases expand. In general, they contract by loss of heat.

The mercurial thermometer makes use of the contraction and expansion of the liquid, mercury, for the purpose of measuring changes of temperature.

The following are some of the properties of mercury which render it especially suitable for this purpose:

Its great range of expansion *as a liquid* from
—39° F. to +662° F. = 701° F.
Its nearly uniform expansion throughout that range.
Its readiness in acquiring the temperature of bodies in contact with it.
Its slight adhesion to glass.
The ease with which it may be freed from air.

57. The two *fixed points* of a thermometer are the freezing point and the boiling point of water.

The Fahrenheit thermometer adopts 32° as the freezing point, and 212° as the boiling point; affording 180 degrees between.

The Centigrade thermometer adopts 0° as the freezing point, and 100° as the boiling point; affording 100 degrees between.

The Réaumur thermometer adopts 0° as the freezing point, and 80° as the boiling point; affording 80 degrees between.

iii. Change of state.

58. Some substances, (as water,) may easily be made to occupy any one of the three states, the solid, liquid, or gaseous.

On the other hand, some liquids, (as alcohol,) have never been solidified; and some gases, (as those of the atmospheric air,) have never been liquefied, much less solidified.

When change of state *does* take place, it is according to the following laws:

To change a solid to a liquid, or a liquid to a vapor, heat must be added.

To change a vapor to a liquid, or a liquid to a solid, heat must be withdrawn.

iv. Work

59. Just as work, expended in the forms of friction or percussion, produces heat, so conversely, the expenditure of heat may be so directed, as to result in the performance of work.

The Steam engine.

(*d*) *Methods of its Transfer.*

60. i. Conduction.—this method is illustrated by an iron bar, one end of which is heated in a fire.

ii. Convection.—illustrated by the heating of air and water.

iii. Radiation—illustrated by the Sun heating the Earth.

3d. The Movements of Atoms.

61. We are by no means certain that there is any motion of atoms within the molecule, without decomposition of the molecule.

CHAPTER III.

Outline of the History of Chemistry.

Chemical Knowledge of the Ancients.

62. The monuments of ancient art yet remaining, and the fragments of ancient literature still preserved, show that the ancients had great skill in technical chemistry, that is, in chemistry applied to the arts.

Thus, the ancient Egyptians smelted ores, made glass and colored it, dyed fabrics by the use of mordants, and made skillful use of antiseptics.

63. The Greeks of the time of Homer (about 850 B. C.) had but little chemical knowledge. While it is a remarkable fact, that the Greek philosophers suggested with greater or less distinctness, many of the theories of physical science

generally regarded as peculiarly modern, yet these views decided nothing, for the metaphysical tendency of the Greek mind prompted to speculation rather than to experiment. The view of Aristotle (about 380 B. C.) as to the nature of material objects is so well known as to need little more than mention. He considered them to be the product of the suitable combination of heat, cold, moisture and dryness. From such combination he supposed the four so-called elements, fire, air, earth and water to be produced.

64. The early Romans knew but little of Chemistry. They neglected even technical chemistry. They despised all mechanical occupations, assigning them to slaves. The principal source of our information upon this subject is the *Historia Naturalis* of Pliny the elder (d. A. D. 79). From this work, we learn that the Romans of his time, knew several of the metals, and prepared glass, soap, vinegar and certain pigments.

The history of chemistry since the Christian era may be briefly presented in six periods.

Chemistry since the Christian Era.

First Period.

From the Christian era to the VIIIth century.

65. This period includes, that from the year 180 A. D. which Gibbon assigns as the time of the beginning of the decline of the Roman empire, to its division in the year 395; that to the fall of the Western empire in the year 476; and that to the year 768, when, after the confusing struggles of the barbarous tribes of Europe, the nations began to assume some rude shape under the rule of Charlemagne. This period, so far as chemical progress is concerned, is characterized by utter barrenness.

Second Period.

From the VIIIth century to the XVIth.

66. This period carries us through the close of the crusades (1095 to 1270); the fall of the Eastern empire, by the taking of Constantinople by the Turks in 1453; and the Renaissance or revival of letters (from 1300 to 1550).

In the VIIth century, Geber, the great Arabian chemist flourished. He was acquainted with many salts and acids. He is remarkable for his presentation of the earliest distinct chemical theory; he is its supporter, although he refers its origin to an earlier date. The theory was, that all the metals are compounds of mercury and sulphur in varying quantity and purity.

To this period, belong the alchemists Albertus Magnus, of Germany (d. 1282), and Roger Bacon of England (d. 1284).

Roger Bacon was the most eminent of English philosophers, prior to the advent of his great namesake, Francis Bacon. In the tenor of their minds indeed, there was no small resemblance.

The purposes of the alchemists were, to discover the *Philosopher's stone* and the *Elixir of Life*, the one supposed to be endowed with the power of creating gold, the other with the power of prolonging existence. With these aims in view, they made great numbers of careful and laborious experiments, but their results were described in such figurative, fantastic and obscure terms as to render them of little value.

Third period.

The XVIth Century.

67. From the fall of the Roman Empire of the West, to the discovery of America, (a period of about 1000 years called the middle ages,) European history presents a scene of the greatest confusion. But the remarkable events of the 15th

century, and the opening scenes of the great Reformation, prepared the way for the great advances in chemistry, witnessed by the succeeding centuries.

68. Paracelsus of Switzerland, of this period (d. 1541), was preëminently a pretentious quack, yet he is entitled to mention. He first called the attention of physicians to the importance of chemical remedies, and so afforded a great stimulus to chemical study.

69. Georgius Agricola (Georg Bauer) of Saxony (d. 1558), at about the same time, introduced immense improvements in metallurgy. He described his processes in clear and appropriate language, which itself marked a great advance upon the mystical forms of expression of the alchemists.

Fourth Period.

The XVIIth Century.

70. During the XVIIth century, Chemistry emerged from the clouds of superstition which had shrouded it. It ceased to have its old purposes. It began to advance toward what it now is: the serious study of Nature for the purpose of acquiring a knowledge of the laws which govern Nature.

During this century arose Johann Joachim Becher (d. 1682) and Georg Ernst Stahl (d. 1734), the former the suggestor, and the latter the earliest supporter, of the famous theory of Phlogiston. This theory they applied to the explanation of the phenomena of combustion, the great problem of that day.

In order, at once, to explain the views of the supporters of the Phlogistic theory, and to compare them with the views of chemists of the present day, let us consider three cases of combustion: (a) the combustion of Carbon, (b) the combustion of Lead, (c) the reaction when Carbon is heated with Plumbic oxide.

The Modern View.

71. (a) Unburnt carbon possesses potential energy. It can combine with Oxygen to form an oxidized product called Carbonic anhydride (CO_2).

The oxidized product is a colorless gas, so that the Carbon disappears almost entirely; but if the CO_2 be collected and weighed, its weight is found to be greater than that of the original Carbon.

If any residue is left after combustion, it is the ash, i. e. the mineral matter, originally forming a part of the wood, from which the charcoal was obtained.

At the termination of the combustion, the Carbon has given up its energy (in the form of heat) to neighboring substances, as for example, the atmospheric air.

(b) Before burning, metallic Lead possesses potential energy.

It can combine with Oxygen to form a sort of ash called Plumbic oxide (Pb O).

The product of combustion is a solid, which may readily be weighed. It is known to be of greater weight than the original Lead, from which it is produced. At the termination of the combustion, the Lead has given out its energy to neighboring substances.

(c) Carbon possesses potential energy; Plumbic oxide has lost the energy it possessed as Lead.

The Carbon and Plumbic oxide may be made to react as follows:

$$2PbO + C = 2Pb + CO_2$$

That is, the Carbon escapes as Carbonic anhydride gas; the Plumbic oxide changes to metallic Lead.

During the reaction, the Lead has acquired energy from the Carbon, which latter has lost energy.

The Phlogistic View.

72. The Phlogistic chemists were acquainted with these three experiments. They explained them somewhat as follows:

(a) Charcoal possesses (first) a small quantity of a material part, and (secondly) a larger quantity of a gaseous or fiery or etherial, but very indistinctly described *something*, called Phlogiston.

The process of combustion is simply the escape of Phlogiston.

The dephlogisticated or material residue, left after combustion, is very small in quantity, because the Phlogiston is the principal constituent of the charcoal.

(b) Lead has (first) a material part, and (secondly) a small amount of Phlogiston.

The process of combustion is the escape of Phlogiston.

The residue is called a Calx of lead or dephlogisticated Lead. Its amount is large, because Lead does not contain much Phlogiston. (Indeed the Calx of lead weighs more than the original Lead, but this is a fact of no great significance).

(c) When charcoal is heated with Calx of lead, the charcoal disappears, and metallic Lead appears. The change may be expressed, by saying that charcoal has given all its Phlogiston to rephlogisticate the dephlogisticated Lead; or, in other words, phlogisticated charcoal and dephlogisticated Lead, produce phlogisticated Lead and dephlogisticated charcoal.

73. This great theory overlooked the importance of the ponderal relations of chemical changes. Though it did not long remain as simple and consistent as the foregoing brief description represents it, but soon became loaded with ridiculous inconsistencies, yet it contained a germ (which remained long undeveloped) of the modern view of the conservation of energy.

Fifth Period.

The XVIIIth Century.

74. In this century appear prëeminent, the names of
Joseph Black of Scotland;
Henry Cavendish and Joseph Priestley of England;
Torbern Bergman, and Karl Wilhelm Scheele of Sweden;
Antoine Laurent Lavoisier of France.

Black (d. 1799) explained the relations of Carbonic anhydride gas to the alkalies. He also described the phenomena of latent heat.

Cavendish (d. 1810) discovered the composition of water.

Priestley (d. 1806) invented the pneumatic trough and discovered Oxygen.

Bergman (d. 1784) and Scheele (d. 1786) were fruitful discoverers and skillful analyists. The latter discovered Oxygen and Chlorine.

Lavoisier (d. on the scaffold in Paris, 1794) was the most illustrious chemist of the century. He appears most prominent as the originator, and eminently successful supporter, of the anti-phlogistic view of combustion, and as the demolisher of the theory of Phlogiston.

He proved that when a metal, as Mercury for instance, is burned, its gain in weight is important, as being due to something absorbed by the metal; that the ***something absorbed*** is Oxygen derived from the atmospheric air; that the Mercury and Oxygen so combined, may be separated again, so that each shall reappear with all of its ordinary properties.

We are also largely indebted to Lavoisier for the admirable system of chemical nomenclature, which, with some modifications, is still in universal use.

Sixth Period.

The early part of the XIXth century.

75. Perhaps the three most prominent names of this period, are Sir Humphry Davy and John Dalton, of England; and Johan Jakob Berzelius of Sweden.

Dalton (d. 1844) suggested the atomic theory, as based upon the proportions by weight, in which bodies are observed to combine.

Davy (d. 1829) first isolated the metals Potassium and Sodium. He invented the miner's safety lamp.

76. Berzelius (d. 1848) occupies a prominence in the history of chemistry, which has hardly ever been surpassed. His investigations are unexcelled in variety and accuracy. There is scarcely an elementary substance, (known in his life time,) whose properties he did not investigate. He determined the combining numbers of almost all of them. He advanced technical as well as theoretical chemistry. Finally, we are indebted to him for our system of abridged chemical notation.

CHAPTER IV.

The Classifications of Substances.

77. Chemistry treats of the atomic composition of bodies, and of the properties which characterize matter, as a result of differences in the kind, number, and relative position of the atoms which compose the molecule.

The various kinds of matter may be divided into two classes, —elementary substances and compound substances.

Elementary substances, or simple radicles, are those whose molecules are made up of atoms of the same kind. Compound substances, are those whose molecules are made up of atoms of different kinds.

It is evident that all compound molecules are both constructed from elementary molecules, and may, by molecular re-arrangement, be again resolved into elementary molecules.

Elementary Substances.

78. At present, we know of but 63 elementary substances of which but 29 were known at the beginning of the present century.

The following is a list of the elementary substances at present known.

NAME.	SYMBOL.	ATOMIC WEIGHT.	NAME.	SYMBOL.	ATOMIC WEIGHT.
Aluminum	Al	27.5	Molybdenum	Mo	92.
Antimony	Sb	122.	Nickel	Ni	58.8
Arsenic	As	75.	Niobium	Nb	97.6
Barium	Ba	137.	Nitrogen	N	14.
Bismuth	Bi	208.	Osmium	Os	199.
Boron	Bo	11.	Oxygen	O	16.
Bromine	Br	80.	Palladium	Pd	106.5
Cadmium	Cd	112.	Phosphorus	P	31.
Caesium	Cs	133.	Platinum	Pt	197.88
Calcium	Ca	40.	Potassium	K	39.11
Carbon	C	12.	Rhodium	Rh	104.
Cerium	Ce	92.	Rubidium	Rb	85.5
Chlorine	Cl	35.46	Ruthenium	Ru	104.
Chromium	Cr	52.48	Selenium	Se	79.4
Cobalt	Co	58.8	Silicon	Si	28.
Copper	Cu	63.4	Silver	Ag	107.97
Didymium	D	96.	Sodium	Na	23.
Erbium	E	112.6	Strontium	Sr	87.5
Fluorine	Fl	19.	Sulphur	S	32.
Glucinum	Gl	14.	Tantalum	Ta	137.5
Gold	Au	196.	Tellurium	Te	128.
Hydrogen	H	1.	Thallium	Tl	204.
Indium	In	74.	Thorium	Th	231.5
Iodine	I	127.	Tin	Sn	118.
Iridium	Ir	198.	Titanium	Ti	50.
Iron	Fe	56.	Tungsten	W	184.
Lanthanum	La	92.	Uranium	Ur	120.
Lead	Pb	207.	Vanadium	Va	51.2
Lithium	Li	7.	Yttrium	Yt	68.
Magnesium	Mg	24.	Zinc	Zn	65.06
Manganese	Mn	55.	Zirconium	Zr	90.
Mercury	Hg	200.			

79. Of the sixty-three elementary substances, five are *gases* at ordinary temperatures, viz:

Hydrogen.
Fluorine.
Chlorine.
Oxygen.
Nitrogen.

Two are *liquid* at ordinary temperatures, viz:

Bromine.
Mercury.

The rest are solid at ordinary temperatures.

80. The elements are also classified as metals and non-metals. The term *metal* applies to an ideal elementary substance which possesses the following properties:

(a) solidity; high specific gravity; hardness; malleability, and ductility;

(b) lustre; opacity; good conducting power for heat and electricity;

(c) affinity for Oxygen; displacing power toward Hydrogen; marked electro-positive tendencies.

The term *non-metal* is not used with much distinctness. It is applied to substances which possess properties which are very nearly the opposite of those just enumerated.

81. The elements are also classified according to their atom-fixing powers or *equivalences*, into monads, dyads, triads, tetrads, etc.

82. The elements are also classified according to their relations to each other, when influenced by the electrodes of the galvanic battery. *Those substances which are liberated at the positive electrode, are said to be electro-negative with respect to substances which at the same time are liberated at the negative electrode, and which are thence said to be electro-positive.* The terms electro-positive and electro-negative, are

however entirely *relative*. Thus, Chlorine is said to be electronegative in its relations to Hydrogen; it is said to be electropositive in its relations to Oxygen.

Compound Substances.

83. Compound substances appear to be infinite in number.

By artificial means, chemists have been able to form many compounds, which have not yet been recognized as occurring in nature; on the other hand, there exist in nature many compounds, which have not yet been produced artificially.

The influences of *long time*; *high temperature*; *vital force.*

84. For convenience, compounds are placed in two classes: organic compounds and inorganic compounds.

i. Organic compounds are those whose molecules consist of one or more atoms of Carbon, *directly united* either with more Carbon or with Nitrogen or Hydrogen.

CO_2, Carbonic anhydride, is *inorganic.*
H_4C, Marsh-gas, is *organic.*

ii. Organic compounds are usually produced either naturally or artificially, from animal or vegetable substances. The great majority of them are made up of Carbon, Hydrogen and Oxygen; a few of them, especially animal compounds, contain in addition, Nitrogen or Sulphur or Phosphorus or all of them.

CHONSP

iii. Organic chemistry has been called with propriety, the chemistry of the Carbon compounds.

Inorganic compounds are those not organic; they include most mineral compounds.

85. The term *compound radicle* is applied to a group of atoms which can take the place and perform the functions of an

element, in a chemical compound. A compound radicle may, or may not, have a separate existence.

Compound radicles are said to be electro-negative or electro-positive, according to the electro-chemical characteristics of the simple radicles with which they can combine or for which they may be substituted.

BOOK SECOND.

CHAPTER I.

The Non-Metallic Monads.

Hydrogen,	atomic weight.	1
Fluorine,	"	19
Chlorine,	"	35.46
Bromine,	"	80.
Iodine.	"	127.

Hydrogen.

Distribution.

86. Hydrogen occurs *free*, in certain volcanic gases.

The spectroscope shows its existence in the sun, the fixed stars, and some of the nebulæ.

In *combination*, Hydrogen forms one-ninth by weight, of all water, and also an important part of dry animal and vegetable structures.

Preparation.

87. It is prepared by a variety of methods.

First method. The metal Sodium has very strong affinities; when added to water, H_2O, it reacts thus:

$$2H_2O + Na_2 = 2NaOH + H_2$$

88. When the metal Potassium is thrown into water a series of phenomena appear. They may be summarized as follows:

1. Upon exposing the Potassium to the air, the surface portions oxidize; thus,

$$2K_2+O_2=2K_2O$$

Potassic oxide.

2. When it touches the water, the K_2O on the *surface* of the pellet dissolves; thus,

$$K_2O+H_2O=2KOH$$

Potassic hydrate.

3. The metallic portions, upon coming in contact with the water, decompose the latter; thus,

$$2H_2O+K_2=2KOH+H_2$$

4. Reactions 2 and 3 produce heat enough to fuse the Potassium; it rises to the surface of the water and floats, in the spheroidal state, upon the cushion of Hydrogen gas and steam.

5. The heat is sufficient to set the Hydrogen on fire.

$$2H_2+O_2=2H_2O$$

6. The globule of Potassium being highly heated, and in contact with steam and Oxygen of the air, reacts with them as in 2 and 1.

7. As soon as the heat of any of these reactions is sufficient, a portion of the Potassium or Potassic compounds becomes changed into luminous vapor of a violet color.

8. After the foregoing reactions cease and the flame disappears, there remains a fused globule of KOH, floating about in the spheroidal state.

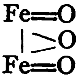
9. As this globule (8) cools somewhat, it becomes no longer able to remain in the spheroidal condition, and eventually drops (while still hot, as compared with the water) into the water. Steam is formed, which, by its expansion, followed by sudden condensation, produces a slight explosion.

89. ***Second method.*** If steam be passed over red-hot iron filings, the iron displaces the Hydrogen and combines with the Oxygen thus,

$$3Fe_2+8H_2O=2Fe_3O_4+8H_2.$$

FeO or $Fe{=}O$ is Ferrous oxide.

Fe_2O_3 or



$$\begin{array}{l} Fe{=}O \\ \;| > O \\ Fe{=}O \end{array}$$

is Ferric oxide.

Fe_3O_4 is Ferroso-ferric oxide.

90. ***Third method.*** The method generally adopted, is to add dilute Sulphuric acid, H_2SO_4, to commercial Zinc. The Zinc displaces the Hydrogen and forms Zinc sulphate, $Zn\ SO_4$.

$$Zn+H_2SO_4=ZnSO_4+H_2$$

Properties of Hydrogen.

91. *Physical.* Pure Hydrogen is a gas which has never been liquified, much less solidified. When pure, it is colorless, odorless and tasteless. It is the lightest form of matter known. If a given volume of Hydrogen has a weight called unity, the same volume of Oxygen has the weight 16, i. e. it is 16 times as heavy.

Animals immersed in Hydrogen perish, not from any corrosive action of the gas, but from deprivation of Oxygen.

92. *Chemical.* One of the most important chemical properties of Hydrogen is its affinity for Oxygen. Hydrogen readily burns, the sole product of the combustion being H_2O, aqueous or water vapor.

In *Döbereiner's lamp* the gas is so evolved as to fall upon a piece of spongy Platinum. The Hydrogen, and the Oxygen of the air) are condensed on the surfaces of the Platinum and are thus brought within the insensible distance, through which chemical union can take place.

Explosive Mixtures. In the cases just described, the Hydrogen burns quietly, combining with Oxygen only gradually, and on the outside of its own mass. But if we mix two volumes of Hydrogen and one volume of Oxygen, and allow them to diffuse together, the mixture is explosive, but not spontaneously so. The explosion is due to the fact that the chemical union takes place simultaneously in all parts of the mass, and

1st. the water-vapor produced is enormously expanded, by reason of the great heat-of-combustion of Hydrogen.

2dly. this vapor is suddenly condensed to water, occupying an extremely small bulk as compared with its preceding stage.

Uses of Hydrogen in Science.

93. i. Owing to its extreme lightness, Hydrogen is *adopted as the standard of density for gases.* (Density is proportional to relative weight.)

The weight of a given volume of Hydrogen being *adopted* as 1, the weight of the same volume of Oxygen is *found to be* 16; the weight of the same volume of water vapor is found to be 9.

The unit of volume usually taken, is the French measure of capacity, called the *Litre.* Its capacity is 1000 cubic centimetres. The weight of one Litre of Hydrogen—at normal temperature and pressure—is .0896 grammes; this weight is called one *crith* (barley-corn.)

94. ii. A single atom of Hydrogen, is *adopted as the standard of atomic weight.* The *absolute* weight of a single atom

of Hydrogen is unknown, but it has received the name of one *micro-crith.* The weight of a single atom of Oxygen is believed to be 16 times that of a single atom of Hydrogen. The atomic weight of Oxygen, therefore, is said to be 16; i. e. 16 micro-criths.

Chemists assign to each element a number, called its atomic weight. Now, Hydrogen being adopted as the standard of atomic weight, it remains to describe how the atomic weights of other substances are learned. But it must not be forgotten, that to fix upon the atomic weight of a substance, (as distinguished from some *multiple* or some *fraction of it,*) is a matter of no slight difficulty. It demands two distinct kinds of operations ; *first,* testing and analyzing substances,—this is the manual or mechanical part ; *secondly,* drawing the proper inferences from the results of analysis and experiment,—this is the higher and more difficult work.

There are four principal data for the formation of an opinion as to the true atomic weight of an element.

95. (a). If possible, the *density of the substance itself in the state of gas,* should be learned by experiment. Double this number, represents the molecular weight sought.

Thus, the observed density of Oxygen is 16. Double this is 32, the molecular weight of Oxygen; but all elementary substances are, at first, assumed to contain two atoms in the molecule; hence the atomic weight of Oxygen will be one-half its molecular weight, i. e. 16.

96. (b). The *density of some gaseous compound* formed by the element in question with Hydrogen or some other substance of known atomic weight, is to be ascertained; of course, the compound selected, must be that containing the smallest known proportion of the element, whose atomic weight is sought.

Now, the density of water-vapor is found by experiment to be 9, whence its molecular weight must be twice 9, or 18. If the result of process (a) is correct, then the composition of water is 16 parts, or probably one atom of Oxygen, combined with 2 parts or two atoms of Hydrogen. Its formula is probably H_2O.

97. (c). There must be performed an *analysis of the simplest compound formed by the element in question with Hydrogen, or with some other element of known atomic weight.*

Now, experiment shows that two volumes of water-vapor are composed of *two volumes* of Hydrogen combined with *one volume* of Oxygen. In accordance with Ampère's law, this suggests that there are, in water, twice as many atoms of Hydrogen as of Oxygen, which accords with the views already adopted.

Again, analysis shows that water is composed of 1 part *by weight*, of Hydrogen, combined with 8 parts *by weight*, of Oxygen.

But the volume relations just referred to, indicate that the molecule of water must contain at least two atoms of Hydrogen, combined with at least one atom of Oxygen. Therefore, the weight-ratios may be properly expressed as 2 parts of Hydrogen, to 16 parts of Oxygen. And this view sustains the theory already adopted, that the atomic weight of Oxygen is 16.

98. (d). In the case of solids, *the specific heat* of the substance is of value in discovering atomic weights. For it has been observed that a certain number (6.34), divided by the specific heat of a substance, gives almost exactly its atomic weight. Thus, 6.34 divided by the specific heat of Iron, .1138 = 55.71. The true atomic weight of Iron is believed to be 56.

99. iii. Hydrogen is *adopted as the standard of equivalence* or *atomic-fixing power*. An atom that can combine with, or take the place of one atom of Hydrogen is called a monad and is said to be univalent.

Thus Chlorine is a monad; it forms HCl
Potassium " " " KCl

Similarly, atoms may be dyads, triads, tetrads, pentads, hexads, heptads, and octads; and are said to be bivalent, trivalent, quadrivalent, quintivalent, sexivalent, septivalent, octivalent.

In general, atoms of even equivalence are called *artiads;* those of uneven equivalence, *perissads.*

But the same perissad element may have, at different times, the different equivalences 1—3—5—7, and the same artiad may have, at different times, the different equivalences, 2—4—6, and sometimes 8.

How explained.

Uses of Hydrogen in the Arts.

100. Hydrogen, owing to its lightness, was formerly used in the inflation of balloons; but coal-gas being now much cheaper, is generally used at present.

Hydrogen is sometimes used in connection with Oxygen or air, as a compound blow-pipe for the production of intense heat.

Fluorine.

Chlorine, Bromine, Iodine.

101. These substances belong to a family, and are marked by striking resemblances and differences.

Fluorine,	Fl.	—		atomic wt.	19.	
Chlorine,	Cl;	gas;	green;	atomic wt.	35.46	
Bromine,	Br;	liquid;	red;	"		80.
Iodine,	I;	solid;	purple;	"	127.	
					162.46	

Of the last group, Chlorine has the strongest affinities; Iodine the weakest; those of Bromine are intermediate.

They are all obtained from the same sources; viz., from the water of the ocean and of mineral springs, in which they exist as Chlorides, Bromides and Iodides.

Chlorine.

(discovered by Scheele in 1774.)

Distribution.

102. Chlorine is not found free in nature. It is found combined with the metal Sodium forming NaCl (common salt,) in sea water, water of saline springs and in fact, in almost all water.

NaCl, Sodic chloride, is also found in the form of solid deposits in many parts of the earth.

Preparation.

103. It is prepared from Manganese di-oxide, by the addition of Chloro-hydric acid, HCl, thus,

$$MnO_2+4HCl=Cl_2+MnCl_2+2H_2O.$$

Properties.

104. *Physical.* At ordinary temperatures it is a greenish gas (density 35.46).

It is heavier than air, and is collected by displacement of air.

Density of air,=14.4, (see p. 14)

It may be liquified by cold and pressure, but has never been solidified.

It has a very suffocating and corrosive odor.

It is very soluble in water.

105. *Chemical.* It is characterized by very energetic chemical properties. In fact, it forms compounds with nearly all the elements.

(a). It has a strong affinity for the metals, and with them it forms chlorides. Even Gold cannot resist its action.

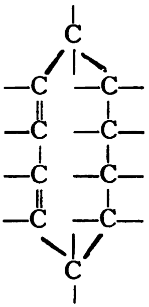
Its reaction with Antimony is as follows:

$$Sb_2Sb_2+10Cl_2=4SbCl_5.$$

(b). It has a strong affinity for Hydrogen. A jet of burning Hydrogen continues to burn in chlorine. A candle of paraffine burns, but only its Hydrogen combines with the Chlorine; its Carbon is set free.

Paraffine is the term applied to a solid substance which is composed of a mixture of several of the higher members of the Hydro-carbon series represented by C_nH_{2n+2}. Its components are in the neighborhood of the compound. $C_{30}H_{62}$.

Turpentine is $C_{10}H_{16}$



It takes fire spontaneously in Chlorine gas, but only its Hydrogen combines; its Carbon is set free.

Uses of Chlorine.

1st, As a Bleaching Agent.

106. Enormous quantities of Chlorine are used in the preparation of paper and of cotton and linen goods.

Not for wool and silk.

Cotton goods were formerly bleached by exposure to the sun and air on lawns. Soon after the discovery of Chlorine and of its bleaching powers, the Chlorine dissolved in water came to be used.

Objections.—Annoying in respiration; action on metallic substances, etc.

107. At present, the Chlorine is stored up in lime, in the form of a white substance called Bleaching powder.

In preparing the powder, quicklime is first slacked,

$$CaO + H_2O = \underset{\text{Calcic Hydrate}}{CaO_2H_2}$$

Next, Chlorine is supplied to it, thus,

$$2CaO_2H_2 + 2Cl_2 = \underset{\text{Bleaching powder.}}{[CaCl_2O_2 + CaCl_2]} + 2H_2O$$

Bleaching powder is a mixture of Calcic hypochlorite with Calcic chloride.

But the *Bleaching powder* itself, has but feeble powers until some acid is applied to it. An acid withdraws the Calcium, and forms a salt of Calcium, the Chlorine being at the same time liberated.

Thus, $CaCl_2O_2 + CaCl_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + 2Cl_2$

108. The bleaching power of Chlorine is doubtless due to its affinity for Hydrogen. It is observed, moreover, that in a perfectly dry condition, Chlorine does not bleach. (It must be remembered that the coloring matters bleached are *organic* and composed of Carbon, Hydrogen, and Oxygen.) Now, the *first theory*, and that generally received, is that the Chlorine withdraws Hydrogen from the moisture present, and so liberates Oxygen, and that this Oxygen oxidizes the organic coloring matters into new and colorless compounds.

The *second theory* is that the Chlorine withdraws Hydrogen immediately from the colored compound itself, and so breaks it up and renders it no longer colored. This view supposes that the moisture merely serves as a solvent for the Chlorine, and thus brings it into more intimate contact with the coloring matters to be decomposed.

2dly. As a Disinfectant.

109. The offensive and poisonous gases arising from the decomposition of animal and vegetable matters, usually

contain Carbon and Hydrogen, and sometimes they have, in addition, Oxygen, Nitrogen, Sulphur, or Phosphorus, or all of them. Chlorine, acting upon the moisture ever present in the air, liberates Oxygen, which, by a slow combustion burns up the offensive gases.

Bromine.

110. Bromine is a liquid at ordinary temperatures, but it is very volatile and easily changes to the gaseous form. (boils at 150° F.)

Its odor resembles that of Chlorine.

Its chemical properties resemble those of Chlorine in kind, but they are weaker in degree.

(a) With the metals it forms Bromides, as Argentic bromide, $AgBr$, Potassic bromide KBr.

(b) It has a strong affinity for Hydrogen, and forms Bromo-hydric acid, HBr.

It has bleaching powers, but they are less active than those of Chlorine.

Iodine.

111. Iodine is, at ordinary temperatures, a crystalline solid. By heating, it easily changes to a purple vapor.

(a) It forms Iodides of the metals, as, Argentic iodide, AgI, Potassic iodide, KI.

(b) It combines with Hydrogen, forming, Iodohydric acid, HI.

It has feeble bleaching powers.

One of its most striking properties is that of affording a blue color when precipitated on the surface of starch, ($C_6H_{10}O_5$).

Uses of Bromine and Iodine.

112. Bromine and Iodine are largely used in medicine and in photography.

Fluorine.

113. The principal source of Fluorine is the mineral, Fluor-spar, $Ca\ Fl_2$.

But little is known of the properties of Fluorine, but it is believed to be a colorless gas.

With Hydrogen it forms Fluohydric acid, HFl, a colorless gas which possesses the remarkable property of etching glass; it cannot be preserved in glass or porcelain vessels.

The acid is now much used in the arts for marking ornamental glass.

The Metallic Monads.

Silver; Potassium, Sodium, Lithium.

Silver. 107.97.

114. Silver is found in the earth native, that is, in the free or uncombined state. It is also found combined with Sulphur, Chlorine, etc.

It has only very weak affinity for Oxygen, in fact it does not oxidize even when exposed to Oxygen at a high temperature. This property of Silver allows it to be separated from Lead by the process of cupellation. In conducting this process, the alloy of Lead and Silver is subjected to a current of air when at a high temperature. The Lead oxidizes into Plumbic oxide, PbO, which melts and is drained off. The pure Silver is left behind.

The Alkali Metals.

115. Potassium, Sodium, and Lithium are called alkali metals. They form a family and are characterized by similar relations.

	Atomic weights.		Densities of the solid metals.
K	39.11		.86
Na		23	.98
Li	7.		.58
	46.11		

Physically they all resemble each other,—for they are soft white metals like lead, only they are all very light, being lighter than water, and Lithium being the lightest *solid* known.

They rapidly oxidize upon exposure to the air, and if heated in the air, they burn, forming Potassic oxide, K_2O, Sodic oxide, Na_2O, Lithic oxide, Li_2O.

When salts of Potassium, Sodium, or Lithium are highly heated, they vaporize and emit light of a characteristic color,

Potassium salts emit a violet light
Sodium " " an orange light
Lithium " " a crimson light.

116. The oxides of these metals, easily dissolve in water and form hydrates,

KOH—Potassic hydrate.
$NaOH$—Sodic hydrate.
$LiOH$—Lithic hydrate.

Indeed the same compounds are formed when the metals themselves are thrown upon water.

These hydrates possess an acrid, caustic taste, and are called *alkalies*. A characteristic property of an alkali is, that after an acid has reddened a vegetable blue color, an addition of alkali will return the original bluish shade.

117. The salts of Potassium and Sodium are very numerous and many of them are of great importance. But our limited space allows us to refer to but one, here.

Common Salt or Sodic Chloride.

118. Common salt is of value;

1st, because, it is both an article of food by itself, and it is used for preserving other food;

2dly, because it is used in the manufacture of large quantities of other salts of Sodium, especially Sodic carbonate Na_2CO_3.

119. Salt is sometimes found in the earth in such purity that it may be sent at once from the mine into the market.

Oftener, however, the rock-salt has to be dissolved in water and then the brine has to be evaporated in such a way that the pure salt may crystallize out, while leaving the impurities in the mother-liquor which may then be thrown away.

To save fuel, brine from salt springs may be several times passed through the *graduation house*, a structure built of fagots and exposed to the prevailing winds. The brine thus concentrates, so that it will pay to evaporate it in pans over a fire.

120. In making salt from sea-water, the water is generally pumped into a series of fields by the sea-side, the fields being supplied with circuitous channels through which the water must flow in a slow but continuous current. Sufficient exposure to the wind and sun is thus afforded to evaporate the water, so that the Sodic chloride, NaCl, crystallizes. It is then raked up into heaps, from which the mother-liquor drains away into the sea, carrying with it the other compounds it originally contained.

CHAPTER II.

The Non-Metallic Dyads.

To this class belong,

(a)	Oxygen,	atomic weight	16	
(b)	Sulphur,	"	32	
	Selenium,	"		79.4
	Tellurium,	"	128.	
			160	

(a) Oxygen.

Distribution.

121. Oxygen is the most abundant and most widely diffused element in nature. In the atmosphere it exists in the free or uncombined condition, but *mixed* with Nitrogen.

In water, it exists *combined* with Hydrogen. It exists in most mineral substances, in a state of combination with other elements. Indeed, about one-half by weight, of the solid crust of the globe, is Oxygen.

Of organic compounds, the majority contain Oxygen combined with Carbon and Hydrogen.

Preparation.

122. *First.* The leaves of vegetables under the influence of sunlight are constantly decomposing the Carbonic anhydride (CO_2) existing in the atmosphere, fixing the Carbon in their structure and evolving the Oxygen.

Secondly. Priestley who discovered Oxygen (in 1774) prepared it by heating mercuric oxide (HgO)

$$2HgO \textit{ heated}{=}2Hg+O_2$$

When Mercury is heated nearly to its boiling point (662° F.) in the air, it absorbs Oxygen, forming HgO; but at a somewhat higher temperature the compound formed is decomposed.

Thirdly. It is ordinarily prepared by heating Potassic Chlorate, $KClO_3$,

$$2(KClO_3) \textit{ heated}{=}2KCl+3O_2$$

But it is found that the reaction proceeds more gradually and at a lower temperature, if some Manganese di-oxide, MnO_2, be present. But the latter takes no part in the *chemical* action.

Properties.

123. *Physical.* Oxygen is a gas which has never yet been liquified. It is colorless, tasteless, and odorless.

Water dissolves a volume of Oxygen equal to .041 of the bulk of the water at 32°F.

Chemical. It is characterized by chemical properties of the greatest activity, the widest range and the greatest usefulness.

124. (i) It is a supporter of combustion, both in the ordinary air and in the unmixed gas; but under the latter circumstances Oxygen burns ordinary combustibles with greater energy, and also burns substances ordinarily considered incombustible.

The products of such combustion are, in general, oxides, and in most cases the combustion is initiated by aid of high temperature.

Decay and rust are forms of slow combustion, in which the process is aided by a thin film of moisture.

125. (ii) Animal respiration is likewise a form of slow combustion. Fresh air is necessary for respiration as well as for combustion. The chimney of a stove removes the deleterious products of combustion and at the same time produces a current whereby fresh oxygen is supplied.

The action of the animal lungs accomplishes both these functions. The inspired air burns the animal tissues; the expired air removes the products of the combustion.

126. (iii) The wide range of the affinities of Oxygen is apparent when we consider the very large number of animal, vegetable and mineral compounds of which it forms a part.

127. (iv) Its value, or usefulness is apparent when we consider its offices in respiration and combustion merely.

Ozone and Antozone.

128. Oxygen appears to be capable of three allotropic modifications:

(a) Ordinary Oxygen; called the passive modification.
(b) Ozone.
(c) Antozone; the last two being active modifications.

Ozone.

129. Ozone appears to contain three atoms of Oxygen in the molecule.

Distribution.

It is observed to exist in the atmosphere at certain seasons of the year, in larger quantities than at others. It is also observed after electrical discharges in the atmosphere or in Oxygen.

Preparation.

First. It may be prepared (i. e. condensed) from ordinary Oxygen by such physical influences as heat, light and electricity, also by a variety of chemical processes. Thus, the slow combustion of Phosphorus and of Ethyl ether, $\left.\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right\}O$, give rise to it.

Secondly. It is also produced by the action of concentrated Sulphuric acid upon Potassic per-manganate,

$$3K_2Mn_2O_8+9H_2SO_4=$$
$$3K_2SO_4+6MnSO_4+9H_2O+5O_3$$

Properties.

130. Ozone differs from ordinary Oxygen,

(a) In having a peculiar odor,

(b) In having active oxydizing powers at ordinary temperatures. It oxydizes silver, indigo; liberates Iodine, etc.

Schönbein's test for Ozone depends upon the fact that it is able, at ordinary temperatures, to liberate Iodine from its compounds, as Potassic iodide, KI.

thus, $6KI+O_3+3H_2O=5KOH+3I_2$

and upon the additional fact that free Iodine precipitates upon the surface of starch granules, and thus gives rise to a deep blue color.

(c) In having the density 24 instead of 16.

Ozone may be instantly returned to the condition of ordinary Oxygen by a temperature of 600° F., while at 212° F. it gradually returns.

Uses.

131. In nature, Ozone is believed to purify the atmosphere by burning up miasmatic exhalations. In the arts, it has been somewhat used for the bleaching of sugar syrups.

Antozone.

132. Antozone is another active form of Oxygen, about which but little is at present known. It is less stable than Ozone. With moisture it forms clouds, probably of Hydrogen peroxide, H_2O_2

Compounds of Oxygen with Hydrogen.

133. Oxygen and Hydrogen combine with great energy, producing heat and light, in other words, Hydrogen is combustible and the two substances manifest great affinity for each other.

The product of the combination is water-vapor. But the flame affords but little light, for *it is a law that while highly heated solids and liquids emit white light, highly heated vapors emit but a feeble light, unless indeed these vapors are very dense, or the heat is very great. The light emitted by highly heated vapors is, however, of characteristic quality.*

The Hydrogen flame easily emits a musical note in a tube of proper size. The note is due to vibrations in the air; the vibrations are produced by sudden alternate heating and cooling of the air, caused by the rapidly repeated extinction and relighting of the gas flame.

134. In ordinary language, Hydrogen and coal-gas are said to be *combustible substances*, and are viewed as being passive, while Oxygen is said to be a *supporter of combustion* and is viewed as active. But this distinction is not wholly just.

The chemical activity between the combustible and the supporter of combustion is mutual and reciprocal. In ordinary combustions, the combustible is the smaller quantity and burns in an atmosphere of Oxygen. But by reversing the conditions and making Oxygen the smaller quantity, it may be shown to burn in an atmosphere of Hydrogen or of coal gas.

The Oxyhydrogen Blowpipe.

Its Construction.

135. It consists essentially of two tubes separately conveying Oxygen and Hydrogen to a small receiver furnished with a single jet. The gases may then be ignited as they flow from the jet.

The source of danger, is the possibility of the formation of an explosive mixture of the gases.

The Sources of its Power.

136. 1st. *The great heat-of-combustion of Hydrogen.*

This is due to the great affinity of Hydrogen for Oxygen. It is expressed in units of heat. A unit of heat is the amount of heat necessary to raise one unit of weight (one pound or one Kilo) of water, through one unit of temperature (from 32° F. to 33° or from 0° C. to 1°).

The heat-of-combustion of any substance is the number of units of heat evolved by burning, in pure Oxygen, one unit of weight of the substance.

The heat-of-combustion of	Hydrogen, is	34,462.
" "	Carbon, (Wood charcoal)	8,080.
" "	Sulphur,	2,220.
" "	Phosphorus,	5,747.
" "	Zinc,	1,330.

(The unit of temperature being from 0° G. to 1° C.)

137. 2dly. The fact that because of the mixing of Oxygen and Hydrogen, combustion is taking place *through-*

out the flame. (In ordinary flames, combustion takes place only on the outer surface.)

Its Effects.

138. Many metals liquify and vaporize in the intense heat of this flame; many substances which are infusible by ordinary agents readily yield to this.

Its Uses.

(a) Formerly, Platinum was worked by hammering and welding together the heated grains of the native substance. At the present day, many pounds of it may be melted at once in a properly constructed crucible of Lime, into which the blast of the blowpipe is directed.

(b) The Drummond or Calcium light is produced by directing the oxy-hydrogen flame against a cylinder of quick-lime (Calcic oxide, CaO). The intense white light is due to the fact that the Lime, even at this high temperature, remains solid.

Other compound blowpipes may be arranged so as to use Oxygen or air in combination with Hydrogen or coal-gas.

Water.

Distribution.

139. Water exists in large quantities in the atmosphere, in animal and vegetable fluids, in animal and vegetable tissues and even in some solid minerals (Alum, Limonite); besides covering *three-fourths* of the earth's surface, as lakes, rivers and oceans.

Composition.

This may be demonstrated both by analysis and by synthesis.

By Analysis.

140. (a) By the action of the galvanic battery upon water, the latter is decomposed; two volumes of Hydrogen appear at the negative electrode and one volume of Oxygen at the positive electrode.

This kind of decomposition is called Electrolysis and the Hydrogen is said to be electro-positive while the Oxygen is said to be electro-negative.

The molecules of water may be viewed as receiving from the galvanic current, some peculiar kind of impulse, such that, while the whole series of molecules between the electrodes is disarranged, only the end molecules undergo permanent decomposition.

1st Stage, $H_2{=}O \qquad H_2{=}O \qquad H_2{=}O;$
2d Stage, $H_2 \qquad O{=}H_2 \qquad O{=}H_2 \qquad O.$

By Synthesis.

141. If a weighed amount of Cupric oxide (CuO) be heated in a glass tube and a current of pure dry Hydrogen gas be passed over it, the Oxygen leaves the copper and combines with the Hydrogen, forming water,

$$H_2+CuO=H_2O+Cu.$$

The water so formed may be collected in a tube of Calcic Chloride ($CaCl_2$) and its amount may be learned by the gain in weight of the $CaCl_2$ tube.

(b) When a mixture of two volumes of Hydrogen and one volume of Oxygen is exploded in an Eudiometer, two volumes of steam or water-vapor are formed. It readily condenses to water, leaving no excess of either gas in the Eudiometer.

Properties of Water.

142. Water, when pure, is blue colored in large masses. It is odorless and tasteless. It is a poor conductor of heat, and of electricity of low tension.

By the addition and withdrawal of heat its expansion and contraction are abnormal between 39½° F. and 32° F. It is most dense at 39½° F. If heated above 39½° it gradually expands. If cooled below 39½° it likewise slowly expands until it reaches 32° when it solidifies, experiencing a sudden expansion of about one-eleventh of its bulk.

Although a few acids surpass water in the *energy* of its solvent power, water exceeds all other liquids in its *range.*

Varieties of Water.

143. Natural waters differ simply in the *character* and *amount* of the impurities they contain; these differences are due mainly to *the part of the natural circulation of the water at which we withdraw the sample* for examination.

The evaporation taking place at the surface of the sea and of all bodies of water, is the principal source of the moisture of the atmosphere; after this moisture has condensed as rain, the most of it returns to the sea by brooks and rivers.

But some of the water, owing to peculiar surface configuration or to greater or less permeability of surface strata, is either *arrested* forming salt lakes, or *diverted*, as when it sinks below the surface and takes a subterranean course. In this latter case it often reappears at the surface by natural fissures as in case of *mineral springs*, or by artificial ones as in case of wells.

144. We may have, therefore, the following varieties of natural water:

(*a*) Rain water.
(*b*) Brook or river water.
(*c*) Sea water or water of salt lakes.
(*d*) Well water.
(*e*) Mineral spring water.

(a) Rain Water.

145. The only impurities of carefully collected rain water are those it absorbs in passing through the atmosphere. They are Oxygen, Nitrogen, Carbonic anhydride, traces of Ammonia gas, and (especially after thunderstorms,) Ammonic nitrate. In the vicinity of large cities (especially where are many manufacturing establishments) rain water also collects organic matters, dust of various kinds, and even Sulphuric acid.

Of course, rain water collected upon *roofs* acquires impurities of greater quantity and of other kinds, from the materials of the roofs and from dust which may have been collecting there.

So much as 1.2 grains of solid residue to the gallon of water* has been obtained from the evaporation of rain water, carefully collected in the city of Paris.

(b) River Water.

146. Rivers derive their water from direct surface drainage, and from springs whose water has taken a short subterranean course.

The *character* of the impurities depends upon the character of the water-shed. Thus water from a sandy soil, contains very little impurity, not only because of the very slight solubility of the sand, but also because it possesses to some extent, the remarkable power of removing both mineral and organic impurities from water filtered through it.

The *amounts* of impurities likewise vary. The water of rivers draining thinly settled territory, contains to the gallon, about 5 grains of impurities, of which about 2½ grains are organic matter. Sometimes, indeed, river water is scarcely less pure than rain water. The amounts of impurities are, of course, much larger when the river receives the drainage of farms and human habitations and factories. Thus the Thames at London Bridge contains 23.8 grains per Am. gallon.

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*In these remarks, the results of water analyses are all expressed in grains to the American or wine gallon of water=58,372.2 grains of distilled water.

English analyses are generally reported in grains per Imperial gallon=70,000 grains of water.

French analyses are reported in grammes per Litre=1,000 grammes of water.

(c) Sea Water.

147. The accumulation of salts which is observed in sea water is due mainly to the fact that mineral matters carried to the ocean by rivers and springs, are left there, while evaporation is constantly removing the pure water.

Of course the sea water of different localities will contain matters of different *quality*, because of the terrestrial strata furnishing them; and of varying *quantity*, because of differences in the relations of evaporation to fresh water supply, and, because of oceanic circulation. Thus, sea-water has an average density of 1.027, and, on the average, has 2,000 grains of solids to the gallon; but Mediterranean water has about 2,200 grains per gallon, while Baltic water varies in different places, from 300 to 1,000 grains per gallon. This greater amount of salts in the water of the Mediterranean, is due partly to its immense evaporation as compared with its supply of fresh water, and partly to the fact, that at Gibralter, the depth is only about 1,320 feet, while, at other places, it is as great as 6,000 feet.

The average composition of sea- water has been found to be as follows:

Water	96.470	per cent.
$NaCl$	2.700	"
KCl	.070	"
$MgCl_2$	.360	"
$MgSO_4$	.230	"
$CaSO_4$	.140	"
$CaCO_3$	.003	"
$MgBr$	.002	"
Loss	.025	"
	100.000	

(d) Well Water.

148. The solvent powers of water are of very wide range; there are but few solid, liquid or gaseous substances, which are not dissolved to some extent by it. In case of rain water, the solvent powers are somewhat further increased by Carbonic anhydride which it acquires from the atmosphere, and which, after falling, it acquires in still greater quantity from the decaying organic matters with which it comes in contact in filtering through the surface strata. Many carbonates, as Calcic carbonate, which are only very slightly soluble in pure water, are much more so in water containing Carbonic anhydride, with which they are supposed to form bi-carbonates.

Well water almost invariably contains the following substances:

$Ca SO_4$	gypsum.
$Ca CO_3$	chalk.
$Mg CO_3$	magnesia.
$Na Cl$	common salt.
$K Cl$	chloride of potassium.
$Si O_2$	sand.
$Fe CO_3$	carbonate of iron.
$Al_2(CO_3)_3$	carbonate of alumina.
———	organic matter.

Occasionally it contains:

$Ca (NO_3)_2$	nitrate of lime.
$(NH_4)_2 CO_3$	carbonate of ammonia.

149. A well water containing, per gallon, 20 grains of mineral matters of the character of those first enumerated, and from 3 to 5 grains of vegetable matters, and which is *free from Nitrates and from Ammonium compounds*, is considered suitable for drinking purposes. Drinking waters containing larger quantities of mineral matters, are thought to produce the *gravel*, and similar diseases.

When wells are situated in thickly peopled districts, their waters often become impregnated with animal matters, which have come from cesspools, etc.; these animal matters, by their partial decomposition, give rise to Ammonia, Nitrates and Nitrites, which thus serve as indicators of the nitrogenous matters in which they originated. If such waters are used for drinking waters, they become highly injurious to health.

For domestic purposes, as *washing and cooking*, it is very desirable to use a water containing less mineral matter than the amounts above specified. Calcic and Magnesic salts impart to the water the peculiarity termed *hardness*. By use of hard water with soap, the Calcium and Magnesium combine with the fatty acid-radicle of the soap, and thus form insoluble, hard, granular, and inactive Calcium and Magnesium soaps, which do not froth, and do not possess the detergent properties of Sodium and Potassium soaps.

Water for Manufacturing Purposes.

150. Water for use in dyeing establishments should not be *hard*, and should not contain much iron salts.

Water used in steam boilers
1st—may *corrode* the boilers, 2dly—may produce *frothing*, 3dly—may produce *scale*.

1st. When water is very pure, as for example when condensed steam is used, the iron is apt to be violently corroded. This difficulty is avoided when the water contains *small* quantities of soluble salts, especially, when such salts, by acting on iron, form an insoluble compound with it.

2dly. If water contains *large* quantities of soluble salts, "frothing" is apt to occur; this is especially the case when the water contains alkaline carbonates, and when a little oil, by some means, works into the boiler. The oil and the alkali form a soap which produces froth.

3dly. *Boiler scale* is a precipitate forming in boilers. Scales are of various kinds. Some waters produce soft muddy deposits while others produce scales which adhere to the bottom of the boiler like layers of rock.

The principal constituent of scale is Calcic carbonate; this salt having been dissolved in the feed-water by Carbonic anhydride is ppt'd when that gas is expelled by the ebullition. Calcic carbonate alone, forms a powdery and not a tough scale. Calcic sulphate is the ingredient which cements the pulverulent $CaCO_3$ and makes it assume the rocky form. The Calcic sulphate possesses the exceptional property of being less soluble in hot water than in cold, so that, although it is *dissolved* in the cold feed water, it *precipitates* as the water is heated. Of course, these two salts, as well as all other slightly soluble salts present in the water, accumulate in the scale more and more, as the original water which was their solvent, evaporates.

(e) Spring Waters.

151. The water of mineral springs differs from ordinary well-water in that it usually contains far greater amounts of mineral matters, and but small amounts of organic matters. These greater amounts are due,

1st. To the fact that mineral waters have filtered to greater depths, and thus have come in contact with larger amounts of mineral matters, and this, too, under great pressure.

2dly. They are usually strongly charged with *gases*, some of which very greatly increase their solvent power. The most common gas, thus present, is *Carbonic anhydride*, but spring waters may contain in addition, *Oxygen*, *Nitrogen*, *Sulphuretted hydrogen* and *Carburetted hydrogen*.

Spring waters may be classified according to the predominating salts in them, into

I. *Carbonated*, II. *Sulphatic* (and *Sulphuretted*,) III. *Chlorinated* and IV. *Silicious*, *spring waters*.

But waters of any one of these classes, except, perhaps, the last, may also be described as *Alkaline*, (when containing mainly Potassium and Sodium, or Lithium salts,) *Magnesian*, *Calcareous* or *Chalybeate*, according to the metal which predominates.

Hydrogen Peroxide, H_2O_2.

152. Oxygen and Hydrogen form this second compound, H_2O_2. It is a liquid which easily decomposes into water, with liberation of Oxygen. It has bleaching powers, but it is too expensive for general use.

Compounds of Oxygen with Chlorine.

153. Of these, there are five, all belonging to the class of *anhydrides*:

Cl_2O Hypochlorous anhydride;
Cl_2O_3 Chlorous anhydride;
Cl_2O_5 Chloric anhydride;
Cl_2O_7 Perchloric anhydride.

154. *An anhydride is a substance which, by combining with water, or some analogous compound, can produce an acid.*

Thus, the foregoing anhydrides react with water as follows:
$Cl_2O + H_2O = 2(HClO)$ or Hypochlorous acid ($H\text{-}O\text{-}Cl$);
$Cl_2O_3 + H_2O = 2(HClO_2)$ or Chlorous acid ($H\text{-}O\text{-}ClO$);
$Cl_2O_5 + H_2O = 2(HClO_3)$ or Chloric acid ($H\text{-}O\text{-}ClO_2$);
$Cl_2O_7 + H_2O = 2(HClO_4)$ or Perchloric acid ($H\text{-}O\text{-}ClO_3$).

155. *An acid is a salt of Hydrogen, such that the Hydrogen may be removed and a metal or metals, a radicle or radicles, may be substituted in its place, thus giving rise to a metallic salt.*

The general formula for an acid is $H\text{-}D\text{-}\overline{R}$, *in which H represents Hydrogen; D represents the linking dyad, usually Oxygen;* $\overline{R}$ *represents an electro-negative radicle (either simple or compound).*

Thus Potassium may be substituted for the Hydrogen in the above acids, and give rise to the following salts:

$KClO$	Potassic hypochlorite	(K-O-Cl);
$KClO_2$	Potassic chlorite	(K-O-ClO);
$KClO_3$	Potassic chlorate	(K-O-ClO_2);
$KClO_4$	Potassic perchlorate	(K-O-ClO_3).

156. *A salt is a ternary linked by a dyad. The general formula of a salt is* $\overset{+}{R}\text{-}D\text{-}\overset{-}{R}$, *in which* $\overset{+}{R}$ *represents an electro-positive radicle (either simple or compound);* D *represents the linking dyad, usually Oxygen; (and it should be remembered that there is usually an atom of linking dyad for each open point of attraction of the metal or positive radicle);* $\overset{-}{R}$ *represents an electro-negative radicle, which may be either simple or compound, but is usually made up of a non-metal combined with saturating oxygen (or with whatever dyad may be performing the linking function).*

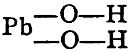
Salts may be viewed as formed by substitution of a metal or other electro-positive radicle, for the Hydrogen of the acid from which the salt is formed.

Salts may be *acid*, *normal* or *basic*.

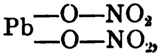
They are called *acid salts* when only a part of the Hydrogen of the original acid is replaced, e. g. HK,SO_4, formed from H_2SO_4.

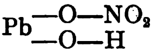
They are called *normal salts* when all the Hydrogen of the original acid is replaced. K_2SO_4 is a normal salt.

They are called *basic* salts after the analogy of the term *base* which was formerly applied to hydrates, such as PbO_2H_2 Plumbic hydrate,



$Pb\begin{smallmatrix}-O-H\\-O-H\end{smallmatrix}$ Now, when the radicle NO_2 is substituted for both atoms of H, we have



$Pb\begin{smallmatrix}-O-NO_2\\-O-NO_2\end{smallmatrix}$, or $Pb(NO_3)_2$ which is the *normal* Plumbic nitrate. When the radicle NO_2 is substituted for only one atom of Hydrogen we have the product  $Pb\genfrac{}{}{0pt}{}{-O-NO_2}{-O-H}$ or $Pb(NO_3HO)$ a *basic* salt, Plumbic nitro-hydrate.

157. There is an important class of salts called *haloid* salts, which are not *ternaries* but are *binaries*. They are formed after the analogy of common salt, $NaCl$.

KI, Potassic iodide, and KBr, Potassic bromide, are examples. They are formed by the substitution of a metal or radicle for the Hydrogen of certain corresponding Haloid acids, such as HCl, Chlorohydric acid; HI Iodohydric acid.

Compounds of Oxygen with Bromine and Iodine.

158. Oxygen forms with Bromine and Iodine, compounds analogous to those formed with Chlorine, but they are rather unstable and of little importance.

With Fluorine, Oxygen is not known to form any compound.

Chemical Nomenclature.

159. Previous to the present century, there prevailed the custom of naming chemical substances in an arbitrary and unsystematic manner. The system of nomenclature now in use has for its object, the application to substances of names such as shall at once indicate their qualitative, and to some extent their quantitative composition.

Names of Elements.

160. No special system is necessary in the case of elements, but it is customary, (a) to allow the names of elements long known, to remain unchanged; (b) to derive the names of new elements, from some well marked property of them; thus Chlorine, a greenish gas, derives its name from *chloros*, green; (c) the names of newly discovered *metals* are made to terminate in *um*, thus, Thallium.

Names of Compounds.

161. Most chemical compounds have more than one name. Sometimes the same compound has three or four different names.

There may be:

(a) A name strictly descriptive of the components, thus, HCl is called Hydric chloride;

(b) A name suggestive of some property of the substance, thus HCl is called Chlorohydric acid;

(c) A commercial name, thus, HCl is called, in commerce, Muriatic acid;

(d) A mineralogical name, thus, PbS is called, properly, Plumbic sulphide; but the mineral substance found crystallized in nature and having the composition PbS, is called Galena;

(e) An arbitrary name. This occurs in the case of many organic compound radicles, thus H_4C is usually called Marsh-gas.

The Strictly Systematic Names.

162. (a) Of Binaries. The name here *involves* the names of both parts of the binary. But the *terminations* of both names are changed. The termination of the second name (which is always that of the more electro-negative substance) is always changed to *ide*. The termination of the first name, (which is always that of the more electro-positive substance,) is changed to *ous* or *ic*, according to the equivalence of such first part. But *ous* is usually employed for lower, and *ic* for higher equivalences:

Thus, $\overset{\text{VI}}{S}O_3$ is Sulphuric oxide; and $\overset{\text{IV}}{S}O_2$ is Sulphurous oxide.

(Note as exceptions to the *use* of the strictly systematic names, the use of the terms anhydride, haloid acids, and compound radicles.)

Prefixes are sometimes used. They may be *numeral*, as Manganese di-oxide for MnO_2; or they may be *general*; thus, the prefix *hypo* is used for a lower, and *per* (abbreviation for hyper) is used for a higher equivalence.

163. (b). Of Ternaries. The principal ternary compounds are salts. In naming a salt, the names of only two of the constituents are usually involved. The third constituent is so often Oxygen that the name of this element is *understood*. But if the linking dyad is Sulphur, its name is expressed. The two constituents whose names are always expressed are the metal and the non-metal which is the basis of the compound radicle. The latin name of the metal is often used, and it is made to terminate in *ic* for higher and in *ous* for lower equivalences; the name of the non-metal is made to terminate in *ate* when the salt is formed from an *ic* acid, or in *ite* when the salt is formed from an *ous* acid.

Thus Ferrous sulphate, $FeSO_4$, is formed from an *ic* acid, that is, H_2SO_4 or Sulphuric acid; and Ferrous sulphite, $FeSO_3$ is formed from an *ous* acid, that is H_2SO_3 or Sulphurous acid.

The following formulas illustrate the analogy of sulphur salts to ordinary oxygen salts:

H_3AsO_3 is Arsenious acid;
H_3AsO_4 is Arsenic acid;
K_3AsO_4 is Potassic arsenate, or in full, Potassic oxy-arsenate;
K_3AsS_4 is Potassic sulpho-arsenate.

Chemical Notation.

164. In Chemical notation, abbreviated expressions indicating the qualitative and quantitative composition of molecules are employed. These expressions are called formulas or symbols. Chemical formulas may be literal, graphic or glyptic.

Literal Formulas.

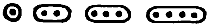
165. Of Elements. An atom of an elementary substance is usually indicated by the initial (sometimes with the addition of another letter) of its native or Latin name, thus :

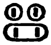
C indicates one atom of Carbon;
Ca " " Calcium;
Cd " " Cadmium;
Ce " " Cerium;
Cl " " Chlorine;
Co " " Cobalt;
Cr " " Chromium;
Cs " " Cæsium;
Cu " " Copper (cuprum).

166. Of Compounds. The symbol of a compound is formed by grouping together the symbols of the elements composing it. It is customary to place the most electro-positive substance first, and in general to arrange the symbols so as to follow the order of the parts of the name of the compound. But, where no special effort is made to indicate the arrangement of atoms in the molecule, the formula is said to be *empirical*; thus HNO_3 for Nitric acid. Where such attempt is made, the formula is called *rational*; thus the rational formula of Nitric acid is $H—O—(N\equiv O_2)$.

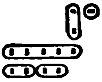
Graphic Formulas.

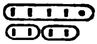
167. Of course all graphic formulas are rational formulas. M. Kékulé employs the following symbols :

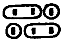


to represent monad, dyad, triad and tetrad radicles respectively. By combinations easily understood, the symbols of compounds may be represented. Thus the symbol  represents the combination of two monad atoms with a dyad, as e. g. H_2O.

By this system, Nitric acid, HNO_3, is represented thus,

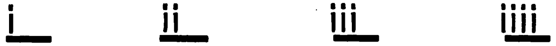


and its compound radicle, NO_2 thus, 

Mercuric chloride, $HgCl_2$ is represented thus, and Mercurous chloride Hg_2Cl_2 

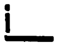
168. A simple and useful method of representing acids is as follows:

HNO_3 H_2SO_4 H_3PO_4 H_4SiO_4

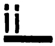


Of course these diagrams represent in general, acids having, respectively, one, two, three, four atoms of replaceable Hydrogen and one, two, three, four atoms of linking oxygen attached to suitable electro-negative radicles.

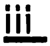
A large number of the possible salts formed by such acids with monad, dyad, triad, and tetrad metals or positive radicles, may be indicated by the simple combination of symbols similar to those just indicated.



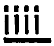
KNO_3



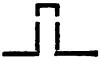
K_2SO_4



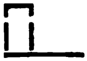
K_3PO_4



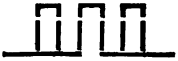
K_4SiO_4



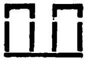
$Pb(NO_3)_2$



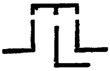
$PbSO_4$



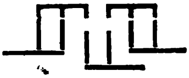
$Ca_3(PO_4)_2$



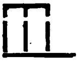
$Ca_2(SiO_4)$



$Bi(NO_3)_3$



$Bi_2(SO_4)_3$



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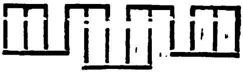

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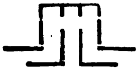
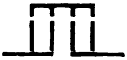
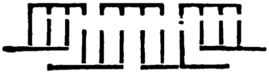
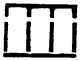
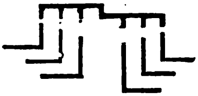


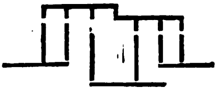








$Fe_2(NO_3)_6$



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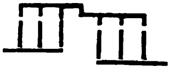
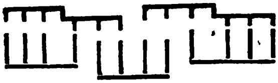


$Fe_2(PO_4)_2$



Glyptic Formulas

169. Glyptic formulas are those in which compounds are represented by models, such as spheres, polyhedrons, etc.

Sulphur, Selenium and Tellurium.

170. These substances form a well marked family group, whose members are characterized by certain striking resemblances.

Thus, their atomic weights bear a simple relation to each other, (see page 47), that of Selenium being almost exactly the mean of the other two—moreover Selenium has affinities intermediate in energy between those of Sulphur, which are stronger, and those of Tellurium which are weaker.

171. They form compounds with Hydrogen, thus:
H-S-H, H_2S Sulphuretted Hydrogen;
H-Se-H, H_2Se Selenuretted Hydrogen;
H-Te-H, H_2Te, Telluretted Hydrogen.

These compounds are gaseous and of disagreeable odor; they act as haloid acids and form haloid salts, called respectively Sulphides, Selenides, and Tellurides.

They form two classes of anhydrides and thence two classes of acids and of salts, thus:

SO_2,	Sulphurous anhydride,	SO_3,	Sulphuric anhydride.
SeO_2,	Selenious "	SeO_3,	Selenic "
TeO_2,	Tellurous "	TeO_3,	Telluric "

H_2SO_3,	Sulphurous acid.	H_2SO_4,	Sulphuric acid.
H_2SeO_3,	Selenious "	H_2SeO_4,	Selenic "
H_2TeO_3,	Tellurous "	H_2TeO_4	Telluric "

K_2SO_3	Potassic Sulphite.	K_2SO_4	Potassic Sulphate.
K_2SeO_3	" Selenite.	K_2SeO_4	" Selenate.
K_2TeO_3	" Tellurite.	K_2TeO_4	" Tellurate.

Selenium and Tellurium are rare and have few practical applications; but Sulphur is extremely abundant and important in the arts.

Sulphur.

172. Sulphur is found *free* in the earth in certain volcanic countries, as Sicily and Iceland. It exists ***in combination*** in great abundance in the form of metallic sulphides, also called pyrites.

Sulphur is prepared by sublimation from sulphur earth or from pyrites. In commerce, it appears in a fine white powder called *lac sulphur*, and in a fine yellow powder called *flowers of sulphur*, and in yellow sticks called *roll brimstone.*

Its Allotropic Modifications.

173. Sulphur exists in three allotropic modifications.

1st. As found crystallized in nature, or as crystallized from its solution in Carbon-di-sulphide CS_2, it appears as orthorhombic octahedrons of the 4th system of crystallization.

2dly. As crystallized from fusion, it forms monoclinic prisms of the 5th system.

3dly. When heated to about 250° C. and then thrown into water, it forms a soft sulphur which is plastic and easily moulded. It is amorphous.

These three forms of Sulphur differ in many of their physical properties, but may be eventually transformed into each other without loss of weight.

Its Uses.

174. Sulphur is largely used in the manufacture of Sulphuric acid, (the most largely used acid of commerce); in the bleaching of straw and woolen goods; and in the manufacture of friction matches.

Compound of Sulphur with Hydrogen.

175. H_2S, Sulphydric acid, or Sulphuretted Hydrogen. This is a colorless gas, having the offensive odor of rotten eggs.

It is used in the laboratory in the testing of metals, to many of which it readily yields its sulphur, and so forms Sulphides of characteristic color.

Compounds of Sulphur with Oxygen.

(a) SO_2, Sulphurous anhydride.

176. This is the product of the combustion of Sulphur in Oxygen or in air.

It is a colorless gas having a disagreeable and choking odor, characteristic of a burning sulphur match.

It readily and abundantly dissolves in water, forming Sulphurous acid H_2SO_3.

Straw and woolen goods are bleached by hanging them in chambers in which sulphur is burning, i. e., by subjecting them to the action of Sulphurous anhydride.

(b) SO_3, Sulphuric anhydride.

177. Sulphuric anhydride is a white solid. It energetically combines with water to form Sulphuric acid, H_2SO_4, a heavy, oily liquid.

H_2SO_4, Sulphuric acid.

178. The manufacture of H_2SO_4 is carried on on an enormous scale. The reactions are conducted principally in large leaden chambers.

The process may be *viewed* as containing four stages.

(i) Sulphur is burned into SO_2 and the gas is conducted into the first chamber.

(ii) The SO_2 meets with some oxide or oxides of Nitrogen, of which N_2O_4 may be taken as the type. A reaction takes place of which the following is the type:

$$2SO_2+N_2O_4=2SO_3+N_2O_2$$

(iii) Jets of steam are blown into the chamber. The water reacts with the SO_3 thus:

$$SO_3+H_2O=H_2SO_4$$

(iv) The Nitrogen di-oxide N_2O_2 takes on oxygen from the air of the chamber and forms a new portion of N_2O_4 thus:

$$N_2O_2+O_2=N_2O_4$$

The N_2O_4 thus formed, is now ready to react upon a new portion of SO_2 as in stage (ii) of the process.

The "pan acid" prepared by this process, is rather dilute and must be afterwards concentrated by evaporation in Platinum stills.

Properties of Sulphuric acid.

179. (a) The acid of commerce is a heavy oily liquid.

(b) It has a strong attraction for water; in fact, it rapidly absorbs moisture from the atmosphere.

(c) When it mixes with water, great heat is evolved.

(d) It chars organic matters—withdrawing water from them and leaving a black mass consisting mainly of carbon.

It acts thus on such compounds, as:

$$\left.\begin{array}{l}\text{Woody fibre}\\ \text{or Cellulose}\end{array}\right\} C_6H_{10}O_5;$$

$$\left.\begin{array}{l}\text{Cane sugar}\\ \text{or Saccharose}\end{array}\right\} C_{12}H_{22}O_{11};$$

$$\left.\begin{array}{l}\text{Grape sugar}\\ \text{or Glucose}\end{array}\right\} C_6H_{12}O_6.$$

(e) The Sulphuric acid radicle SO_4 has very strong affinities for metals, so that it easily *displaces* other radicles and combines with the metals, thus:

$$BaCl_2+H_2SO_4=BaSO_4+2HCl$$

Hence it is much used in the manufacture of other acids.

(f) It has a very sour taste, and strongly reddens litmus.

Uses of Sulphuric acid.

180. Its most important uses are:

(a) In the manufacture of other acids.

(b) In bleaching of cotton goods.

(c) To decompose bones, in the manufacture of artificial fertilizers.

(d) In the manufacture of Soda-ash (Na_2CO_3) by Leblanc's process.

(The Soda-ash is an article of enormous consumption in the bleaching of cotton goods, the scouring of wool, and the manufacture of soap and of glass).

The Metallic Dyads.

They are:

	Lead, Pb., 207	
	Barium, Ba., 137	
	Strontium, Sr., 87.5	
	Calcium, Ca., 40	
	Mercury, Hg., 200	
	Copper, Cu., 63.4	
Cobalt, Co., 58.8	Iron, Fe., 56	Zinc, Zn., 65.06
Nickel, Ni., 58.8	Manganese, Mn., 55	Magnesium, Mg., 24
	Chromium, Cr., 52.48	
	Aluminum, Al., $\frac{55}{2}$	

Lead.

181. Lead is found in nature in great abundance as *galena*, a mineral having the formula PbS.

Metallic lead is of great value in the arts, for a variety of purposes. For the construction of water-pipes it has the advantages of being flexible and easy to solder. It has the disadvantage of imparting to the water, certain salts of lead which are poisonous.

Plumbic carbonate ($PbCO_3$) is called *white lead.* When mixed with oil, it is used for paint.

Barium.

182. Barium salts are much used in fire-works. Barium salts when highly heated afford a green flame.

Strontium.

183. Strontium salts when highly heated afford a crimson flame. They also are used in pyrotechnics.

Calcium.

184. Calcium is the metal of lime (CaO) and limestone ($CaCO_3$). Calcium salts when highly heated afford a red flame.

Many of the Calcium compounds are very useful in the arts.

Quicklime (CaO) when mixed with water, combines with it forming Calcic hydrate (CaO_2H_2) and evolving great heat.

$$CaO+H_2O=CaO_2H_2$$

This Calcic hydrate, with sand (Silicic anhydride SiO_2) and water, forms mortar. The "setting" of mortar is by no means mainly due to its drying. It is mainly due to a chemical reaction between the CaO_2H_2 on the one hand, and the SiO_2 of the sand, and the Carbonic anhydride, CO_2 of the atmosphere, on the other.

$$CaO_2H_2+CO_2=CaCO_3+H_2O;$$
$$CaO_2H_2+SiO_2=CaSiO_3+H_2O.$$

APPENDIX TO CHAPTER II.

Stoichiometry.

185. Stoichiometry relates to the numerical calculations that may be performed in connection with chemical experiments.

These calculations relate to concrete quantity which is expressible by numbers. *These numbers always represent some kind of units.* It is true that sometimes the name of the unit is not expressed; in such case it is invariably *understood.* The following is a brief statement of some of the units used in chemical calculations and of some of their relations to each other:

(a) Units of Length.

186. The English unit, one inch, is derived from the length of the pendulum which vibrates seconds of mean time, in a vacuum, at 62° F., at the level of the sea, and the latitude of London. The length of such a pendulum is adopted as about 39.1393 inches.

The legal unit of length, of the United States of America, is practically the same as the English unit.

The French or Metric unit is derived from the earth's quadrant; one-forty-millionth of which (nearly), is adopted as a unit and called a mètre (39.37 inches nearly). The mètre is multiplied and divided decimally. The *multiples* receive prefixes from the Greek, as décamètre, hectomètre, kilomètre; the *divisions* receive prefixes derived from the Latin, as décimètre, centimètre, millimètre.

(b) Units of Surface.

187. These are derived directly from the linear units.

(c) Units of Volume.

188. These are derived directly from the linear units.

But the English law creates an additional *unit of capacity*, called the *Imperial gallon*, which is the bulk of water weighing (under normal conditions) 70,000 grains or 10 lbs. Avoirdupois. Its volume is found to be 277.274 cubic inches.

The law of the United States establishes the *American or wine gallon* whose capacity is 231 cubic inches. Its bulk of water (under normal conditions) weighs 58,372.2 grains.

The French employ the cubic décimètre (=1000 cubic centimètres) as a new unit of capacity; it is called a *Litre.*

(d) Units of Weight.

189. The English unit of weight is arbitrarily derived from the weight of the Imperial gallon of water. This bulk of water, 277.274 cubic inches is taken as weighing 70,000 grains. The other units of weight are derived as shown in the tables.

The unit of the United States is ultimately derived from the wine gallon in a similar way.

The Metric unit of weight is the gramme. One gramme is the weight of one cubic centimètre of distilled water at its point of greatest density, 4° C.

The calculations necessary for the transformation of numbers of English, American and French units of the kinds (a), (b), (c) and (d) are very simple. (See Tables at the end of the book).

(e) Units of Temperature.

190. When a column of mercury, in a properly constructed thermometer, is heated from the temperature at which (under normal conditions) pure water freezes, to that at which (under normal conditions,) it boils, the summit of the mercury column passes through a certain linear distance.

In Fahrenheit's Thermometer, this distance is divided into 180 units called degrees (from 32° to 212°).

In the Centigrade thermometer, it is divided into 100 degrees (0° to 100°).

In Réaumur's thermometer, it is divided into 80 degrees (0° to 80°).

Forms of Problems.

To change Fahrenheit degrees to Centigrade:

$$C^\circ = \tfrac{5}{9}\,(F^\circ - 32);$$

To change Fahrenheit to Réaumur:

$$R^\circ = \tfrac{4}{9}\,(F^\circ - 32^\circ);$$

To change Centigrade to Fahrenheit:

$$F^\circ = \tfrac{9}{5}\,C^\circ + 32^\circ;$$

To change Centigrade to Réaumur:

$$R^\circ = \tfrac{4}{5}\,C^\circ;$$

To change Réaumur to Fahrenheit:

$$F^\circ = \tfrac{9}{4}\,R^\circ + 32^\circ;$$

To change Réaumur to Centigrade:

$$C^\circ = \tfrac{5}{4}\,R^\circ.$$

(f) Unit of Heat.

Already explained (see p. 52).

(g) Units of Density or Specific gravity.

For Solids and Liquids.

191. The weight of any convenient bulk of the solid or liquid in question is compared with the weight of the same bulk of pure water at *normal temperature;* if the number representing the density or specific gravity of a solid or liquid is greater than 1, it signifies that the substance in question, is so many times heavier than the same bulk of water; if the number is less than 1, it signifies that the weight of the substance is such fractional part of the weight of the same volume of water.

(h) Unit of Density for Gases and Vapors.

192. The weight of any convenient bulk of the gas or vapor in question, is compared with the weight of the same bulk of Hydrogen gas; the gases being under conditions of normal temperature and normal barometric pressure.

The bulk usually referred to, is 1 Litre. One Litre of Hydrogen gas (0°C and 760 m.m. pressure) has been suggested as an additional and special unit of density for gases. Its weight is called 1 crith and is equal to .0896 grammes.

Forms of Problems.

To find the density of a gas, the weight of one Litre of it at normal temperature and pressure being known:

$$D = \frac{\text{W (in grammes) of 1 L.}}{.0896}.$$

To find the weight of 1 Litre of a gas at normal temperature and pressure, its density being known:

$$\text{W (of 1 L.) in grammes} = D \times .0896.$$

(j) Unit of Specific gravity for Gases and Vapors.

193. The term *specific gravity* ordinarily has the same signification as *density*, i. e. relative weight. In the case of gases and vapors, however, the term *density* is employed to express relative weight as compared with *Hydrogen;* the term *specific gravity* has come to be employed to express relative weight as compared with *atmospheric air*. Now, the density of air is 14.45; the specific gravity of Hydrogen is .0693.

Forms of Problems.

To change density to specific gravity, we have only to remember that the unit of specific gravity being 14.45 times as great as that of density, *the number of units* expressing specific gravity in a given case, must be 14.45 times smaller,

$$\therefore \ \text{Sp. Gr.} = \frac{D}{14.45} \text{ or } D \times .0693;$$

To change specific gravity to density:

$$D = \text{Sp.Gr.} \times 14.45 \text{ or } \frac{\text{Sp.Gr.}}{.0693}.$$

(k) Unit of Tension of a Gas, or Unit of Barometric Pressure.

194. A barometer may be constructed by taking a narrow glass tube, of a length exceeding 760 millimètres; closing it at one end; filling it completely with mercury; inverting it so as to insert the unsealed end under the surface of a little basin of mercury. The mercury will be likely immediately to fall a little, leaving a vacuous space above its higher level. The distance in a vertical line between the two surfaces of the mercury, is a measure of the atmospheric pressure upon the lower surface. The average atmospheric pressure is sufficient to maintain the mercury column at a height of 760 m.m., or 29.92 inches.

This 760 m.m. is said to measure the *tension* of the atmospheric air. If the barometer be introduced into a closed vessel containing gas, in which the contained gas has a tension, less than that of the atmosphere, the height (h) of the column of mercury becomes proportionally less; if, in the case last supposed, the tension of the gas is greater than that of the atmosphere, then the height (H) of the mercury column becomes proportionally greater.

$$\therefore \quad \mathfrak{t} : \mathfrak{T} :: h : H,$$

$\mathfrak{t}$, representing the lesser tension, and h, the corresponding lesser height; $\mathfrak{T}$, the greater tension, and H, the corresponding greater height.

But the tension of a gas is inversely as its volume, or,

$$\mathfrak{t} : \mathfrak{T} :: V : v$$

$$\therefore \quad V : v :: h : H;$$

i. e., *the volume of any given weight of gas is inversely as the pressure, expressed in height of barometer*, (H). (See p. 5).

Forms of Problems.

195. To find the *volume of a gas at a given higher pressure*, its volume at a lower pressure being given :

$$v = \frac{VH}{h}.$$

To find the *volume of a gas at a given lower pressure*, from its volume at a given higher pressure:

$$V=\frac{vh}{H}.$$

To find the *greater height of barometer* H, corresponding to a given smaller volume, v, from a given larger volume V, at a given lower pressure h:

$$H=\frac{vh}{V}.$$

To find the *lesser height of barometer* h:

$$h=\frac{VH}{v}.$$

196. But the volume of a gas is also very much altered by slight changes of temperature; the higher the temperature the greater the volume of the gas. (See Charles' law, p. 5).

Let V=the greater volume, at the higher temperature T°, C;
v=the smaller volume, at the lower temperature t°, C.;

then the *higher volume* may be learned from the following equation:

$$V = v\,[1+.003665(T-t)], \ldots\ldots\ldots\ldots [1].$$

The *lower volume* may be learned by finding the value of v, from [1], thus:

$$v=\frac{V}{[1+.003665(T-t)]} \ldots\ldots\ldots\ldots [2].$$

The *difference of temperature*, may be learned in a similar manner from [1], thus:

$$(T-t)=\frac{V-v}{.003665\,v} \ldots\ldots\ldots\ldots [3].$$

(1) Unit of Atomic and of Molecular Weight.

197. This is the weight of one atom of hydrogen. It is as called one microcrith. We do not know its absolute value expressed in grains or grammes. This value is certainly very small.

The atomic weight of Oxygen is expressed by 16: the expression meaning 16 microcriths.

The molecular weight of Carbonic anhydride is 44; meaning, of course, 44 microcriths.

Thus C weighs 12 microcriths;
O_2 weighs 32 "
CO_2 weighs 44 "

198. This explanation, at once shows us *why the number representing the molecular weight of a substance, is twice as great as the number representing the density of the substance in the state of gas;* it is because *the unit of Density is one molecule or two atoms of Hydrogen, while the unit of Molecular weight is one atom of Hydrogen. As the unit of Density is twice as great as the unit of Molecular weight, the number of units expressing Density must be but half as great as the number of units expressing the Molecular weight of the same substance.*

Forms of Problems.

199. Since substances combine and react only by whole atoms, and these atoms have definite weights, it is evident that large numbers of atoms will combine and react in quantities proportional by weight to the atomic weights.

In other words, atomic weights are exactly proportional to mass weights, i. e.,

The atomic weight representing the proper number of atoms of A;	:	The atomic weight representing the proper number of atoms of B;	::	The mass weight of A;	:	The mass weight of B.

To find the *proper number of atoms* of A and B, observe this *Rule:*

Express the chemical change by symbols, in the form of an equation.

Example I.

200 What weight of Oxygen is necessary to change 20 Gms. of Carbonous oxide into Carbonic anhydride?

We first write the reaction, $2(CO)+O_2=2CO_2$;

Then fill out the above proportion.

Twice mol. wt. of CO.		Twice atomic wt. of O.				
56	:	32	::	20 Gms.	:	x Gms,

$$x=\frac{32\times 20}{56}=11.428 \text{ Gms.}$$

Percentage Results.

201. Every finite quantity may be viewed as made up of 100 equal parts, one of those parts being called 1 per cent. Percentage results are obtained when the third term of the above proportion is made to be 100.

Example II.

What per cent. of Oxygen is necessary to change Carbonous oxide into Carbonic anhydride?

$$2(CO)+O_2=2CO_2.$$

Twice mol. wt. of CO,		Twice at. wt. O.				
56	:	32	::	100	:	x

$$x=\frac{32\times 100}{56}=57.14 \text{ per cent.}$$

202. But the uses of the proportion given near the commencement of this section (I) may be much extended; thus:

Let wA = atomic wt. of substance A;
wB = atomic wt. of substance B;
N = number of atoms of A;
n = the number of atoms of B;
WA = mass wt. of A;
WB = mass wt. of B;

then the proportion may be expressed thus:

$$N\times wA : n\times wB :: WA : WB.$$

To find the Value of WB,

We need to know the value of WA; the reaction taking place (so as to fix the value of N and n); the atomic weights of A and B (from a table).

To find the Value of WA.

This is sufficiently explained in the preceding case.

To find the Value of $n \times wB$,

we need to know the values of WA; of WB; of $N \times wA$.

The problem takes this form :

11.428 Gms. of Oxygen are used in burning 20 Gms. of Carbonous oxide into Carbonic anhydride; the molecular wt. of CO_2 is 44; the number of molecules of CO used is 2; what is the molecular wt. of oxygen involved?

$$20 : 11.428 :: 56 : n \times wB = 32.$$

To find the Value of $N \times wA$.

This is sufficiently explained by the preceding case.

To find the Value of n.

Find $n \times wB$; divide this by wB.

To find the Value of N.

Find $N \times wA$; divide by wA.

(m) Unit of Molecular Volume.

203. This is the volume of one molecule of Hydrogen or of two atoms of Hydrogen; it is called two volumes and is expressed thus:

▭□

Every molecular formula is considered to express two volumes of the substance in the form of gas. This fact is often of value in problems.

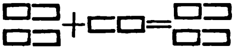
Rule: State the chemical change in the form of a literal equation. Then assign to each factor, a volume equal to 2 volumes for each gaseous molecule.

Example.

204. What volume of Carbonic anhydride will be produced by burning one Litre of Carbonous oxide ?

Answer.

$$2CO + O_2 = 2CO_2.$$



The interpretation of the first equation is this: Two molecules of Carbonous oxide, plus one molecule of Oxygen afford two molecules of Carbonic anhydride.

The interpretation of the second equation in connection with the first is this: Two molecules of Carbonous oxide, occupying four volumes, unite with one molecule of Oxygen occupying two volumes, and give rise to a new product which is two molecules of Carbonic anhydride and which occupies four volumes.

The answer is therefore; one Litre.

CHAPTER III.

The Non-Metallic Triads.

205. These are,

(a)	Nitrogen,	N	14;
(b)	Phosphorus,	P	31;
	Arsenic,	As	75;
	Antimony,	Sb	122.

These substances form compounds, which possess some striking points of resemblance.

206. Thus, with Hydrogen they all form gaseous compounds characterized by marked odors;

H_3N	Ammonia-gas;
H_3P	Phosphuretted hydrogen;
H_3As	Arseniuretted hydrogen.
H_3Sb	Antimoniuretted hydrogen.

207. With Oxygen they form two series of anhydrides, which, with water, form two series of nearly corresponding acids :

N_2O_3	Nitrous	anhydride;	HNO_2	Nitrous	acid;
P_2O_3	Phosphorous	"	H_3PO_3	Phosphorous	"
As_2O_3	Arsenious	"	H_3AsO_3	Arsenious	"
Sb_2O_3	Antimonious	"	$HSbO_2$	Antimonious	"
N_2O_5	Nitric	anhydride;	HNO_3	Nitric	acid;
P_2O_5	Phosphoric	"	H_3PO_4	Phosphoric	"
As_2O_5	Arsenic	"	H_3AsO_4	Arsenic	"
Sb_2O_5	Antimonic	"	$HSbO_3$	Antimonic	"

(a) Nitrogen.

Distribution.

208. In the *free* state, Nitrogen forms about four-fifths of our atmospheric air. Its use here, is simply to dilute the Oxygen and temper its activities. (Although the density of Nitrogen is 14 while that of Oxygen is 16, the latter does not "settle out," but the two remain thoroughly mixed by diffusion).

In *combination*, Nitrogen forms part of a great variety of compounds. In the mineral kingdom, it is found as a constituent of Nitre (Potassic nitrate, KNO_3). It is an important element in many animal matters. It appears to be an essential constituent of muscular fibre, as distinguished from fat, which does not contain it. Hence nitrogenous food is viewed as muscle-forming food, and therefore, more valuable than non-nitrogenous.

Preparation.

209. It is generally prepared by absorbing the Oxygen from the atmospheric air. This is best accomplished by burning Phosphorus in a bell-glass containing air.

$$P_2P_2 + 5O_2 = 2P_2O_5 \text{ (Phosphoric anhydride).}$$

Properties.

210. Nitrogen is a colorless, odorless and tasteless gas which has never yet been liquefied. It is chiefly characterized by a lack of energy. It does not burn. It does not support animal respiration; (though it does not exert any injurious influence upon the organs of respiration).

As a general law, it combines with other substances only by the most circuitous processes. To this there appears to be but one exception. It is in the case of Nitrogen and Oxygen. When the electric sparks of lightning or of an induction coil are passed through atmospheric air, small portions of the gases combine to form N_2O_5; this, with water forms HNO_3; this with NH_3 (always present in the atmosphere) forms $(NH_4)\ NO_3$, Ammonic nitrate, a substance which is almost always found in the rain which falls after discharges of lightning.

211. Strangely enough however, Nitrogen is a constituent of an exceedingly large number of compounds, but,

First. They are generally formed with difficulty;

Secondly. Many of them are easily explosive;

Ordinary cotton or Cellulose $\left.\begin{matrix} C_6H_5 \\ H_5 \end{matrix}\right\} O_5$; Gun cotton or Tri-nitro-cellulose $\left.\begin{matrix} C_6H_5 \\ H_2 \\ (NO_2)_3 \end{matrix}\right\} O_5$;

Ordinary glycerine $\left.\begin{matrix} C_3H_5 \\ H_3 \end{matrix}\right\} O_3$; Tri-nitro-glycerine $\left.\begin{matrix} C_3H_5 \\ (NO_2)_3 \end{matrix}\right\} O_3$;

Thirdly. The animal and vegetable compounds easily decompose.

Compounds of Nitrogen with Hydrogen.

212. Of these, there are three that are especially worthy of remark:

NH_2 called Amidogen;
NH_3 " Ammonia-gas;
NH_4 " Ammonium.

(a) NH_2 is a compound radicle which never has any separate existence, but which is viewed as forming a part of a considerable number of organic compounds called *amines* and *amides*.

Thus, Phenyl (C_6H_5) forms Phenyl-amine, $(C_6H_5)—N=H_2$;
and Acetyl (C_2H_3O) forms Acet-amide, $(C_2H_3O)—N=H_2$.

(b) NH_3 is a colorless gas with a very pungent odor, the odor of *spirits of hartshorn*. It is almost always present in the atmosphere; it is produced by the decay of nitrogenous animal matters.

The gas has a very strong attraction for water, with which it forms a compound, $(NH_4)OH$, called Ammonic hydrate which is an alkali and is in many respects similar to the alkalies of Potassium and Sodium.

The gas also combines directly with acids, forming salts resembling in many respects the salts of the alkali metals.

$NH_3+H_2O=(NH_4)OH$	Ammonic hydrate;
$NH_3+HCl=(NH_4)Cl$	Ammonic chloride;
$NH_3+HNO_3=(NH_4)NO_3$	Ammonic nitrate;
$2NH_3+H_2SO_4=(NH_4)_2SO_4$	Ammonic sulphate.

(c) NH_4 is a compound radicle, which is not known to have any separate existence. It is called a hypothetical metal. It acts like a metal:

1st. In forming salts, e. g., those referred to in the preceding paragraph.

2dly. In forming with Mercury a pasty amalgam which, though not very stable, has metallic lustre. Now, metallic lustre is a property peculiar to metals and alloys and amalgams (an amalgam being a liquid or solid alloy of a metal with *Mercury*).

Compounds of Nitrogen with Oxygen.

213. N_2O, *Nitrogen protoxide*, composed by weight
of 28 parts Nitrogen,
with 16 parts Oxygen,

A colorless gas having the density 22 and hence the molecular wt. 44.

It is called laughing gas; for when inhaled in small quantities it produces exhilaration; in larger quantities it produces insensibility to pain.

N_2O_2 or NO, *Nitrogen dioxide*, composed by weight
of 14 parts Nitrogen,
with 16 parts Oxygen.

It is a colorless gas having the density 15. It readily absorbs Oxygen of the air and forms brown fumes of N_2O_4 (or NO_2).

N_2O_3, *Nitrous anhydride*, composed by weight
of 28 parts Nitrogen,
with 48 parts Oxygen.

With water it forms Nitrous acid, HNO_2.

N_2O_4 or NO_2, *Nitrogen tetroxide*, composed by weight
of 28 parts Nitrogen,
with 64 parts Oxygen.

Its density is anomalous. It is the brown gas already referred to.

N_2O_5, *Nitric anhydride*, composed by weight
of 28 parts Nitrogen,
with 80 parts Oxygen.

With water it forms the powerful acid, Nitric acid, HNO_3.

Nitric Acid, HNO_3.

214. It is usually prepared by adding Sulphuric acid to Potassic or Sodic Nitrate:

$$KNO_3 + H_2SO_4 = HNO_3 + \underset{\text{Hydro-potassic sulphate.}}{HKSO_4},$$

Its Properties.

215. 1st. It is a powerful oxydizing agent, since it contains a large amount of Oxygen, held by a feeble affinity.

2dly. It is an energetic solvent of the metals with which it forms Nitrates.

3dly. Mixed with Chlorohydric acid it forms what is called *aqua regia*, a mixture which has the power (not possessed by either of its ingredients alone) of dissolving Gold and Platinum. The reaction of the two acids when heated together is somewhat complicated, but it is practically as follows:

$$2HNO_3+2HCl=Cl_2+N_2O_4+2H_2O.$$

4th. It is very corrosive in its action upon mineral and vegetable matters. It produces upon animal matters a bright yellow color.

5th. It has a very sour taste and strongly reddens litmus.

Its Uses.

216. It is much used in the refining of alloys of gold with silver, etc., in fact, it is called in commerce "parting acid," because it parts these two metals, by dissolving the silver and leaving the gold untouched. (But before the parting, it is necessary to add to the alloy, so much silver or base metal that the gold shall not exceed 25 per cent. of the whole alloy).

The Atmospheric Air.

217. The gaseous envelope surrounding a body is called its atmosphere. The earth's atmosphere, extending to a height of from 40 to 50 miles, is composed mainly of a mixture of Nitrogen and Oxygen gases.

Composition of the Air.

	By volume.	By weight.
Oxygen	20.9	23.10
Nitrogen	79.1	76.90
	100.0	100.00

218. That the air is a *mixture* and not a chemical compound of these gases, appears from the following facts:

1st. The proportions of Oxygen and Nitrogen in the same portion of air do not bear to each other so simple a ratio as they do in undoubted compounds of these elements; moreover the proportions of Nitrogen and Oxygen in *different portions* of air are more variable than they are in different portions of the same undoubted compound.

2dly. When we mix the proper quantities of Oxygen and Nitrogen, a substance exactly like air is obtained, without the manifestation of any of the signs of chemical action. (Change of color, volume, or physical condition; evolution of heat, etc).

3dly. When air rests in contact with water, the Oxygen and the Nitrogen are dissolved by the water in the following proportions by volume:

100 volumes of the air dissolved in water are made up of,

Oxygen	34.91	volumes;
Nitrogen	65.09	"
	100.00	

Now if the air were a compound, the gases might be expected to be dissolved by the water, in proportions just like those in which they exist in the atmosphere. Further, the proportions just mentioned are what might be expected from a *mixture* of the gases, because of the fact that the coefficient of solubility of Oxygen in water is .041 at 0°C, while that of Nitrogen is .020 at 0°C.

Many other gases exist in the atmosphere in small and variable quantities; thus, aqueous vapor, Carbonic anhydride, (CO_2) and Ammonia-gas are always present.

Phosphorus.

Distribution.

219. This element, though widely diffused in nature, is never found in the free or uncombined condition. It exists in considerable abundance as metallic phosphates. It also

exists in some vegetable matters, either as phosphates or as a constituent of certain complex organic compounds. It also exists in the skeletons of the higher animals and in the brain.

Properties.

220. Phosphorus exists in two well known allotropic forms.

The one best known has the appearance of semi-transparent bees-wax, and it has, at ordinary temperatures a strong affinity for Oxygen. It soon takes fire if exposed to the air.

The second form is called red-phosphorus; it is not readily combustible except at elevated temperatures.

Compounds of Phosphorus with Hydrogen.

221. Phosphuretted hydrogen is prepared by the action of a concentrated and boiling solution of Potassic hydrate upon Phosphorus.

There are three Phosphuretted hydrogens:
H_3P, gaseous at ordinary temperatures;
H_4P_2, liquid " "
H_2P_4, solid " "

The gaseous compound, as prepared by the above mentioned process, also contains some of the vapor of the liquid compound, and it is the admixture of this latter vapor, that renders the escaping gas spontaneously combustible upon entrance into the atmosphere. The products of this combustion are P_2O_5 and H_2O.

Compounds of Phosphorus with Oxygen.

222. When burned in abundance of Oxygen or of air, Phosphorus forms Phosphoric anhydride, P_2O_5. It is a white powder which has great affinity for water, so that it rapidly absorbs moisture from the atmospheric air. If the powder be thrown into water, it hisses from the heat of chemical

union. Phosphoric acid is then produced, in accordance with the following reaction:

$$3H_2O+P_2O_5=2H_3PO_4 \quad (H_3\equiv O_3\equiv\overset{v}{P}O).$$

The brilliancy of the light of this combustion is due to the facts:

(a) That Phosphorus soon vaporizes with the heat afforded by the combustion, and so diffusing throughout the jar, burns in all parts at once.

(b) That the product, P_2O_5 is a solid, and remains so, even when highly heated, and therefore emits a white light.

Arsenic.

223. The most common form of Arsenic in commerce is *white Arsenic*, Arsenious anhydride (As_2O_3). It is very poisonous.

Antimony.

224. This substance occurs in commerce as what is called metallic Antimony.

It is also contained in Tartar-emetic, which is Potassio-antimonylic tartrate.

$$\text{Tartaric acid is } \left.\begin{array}{l} H_2{=}O_2{=} \\ H_2{=}O_2{=} \end{array}\right\} C_4H_2O_2;$$

$$\text{Cream of Tartar is } \left.\begin{array}{l} \left.\begin{array}{l} H \\ K \end{array}\right\rangle{=}O_2{=} \\ H_2{=}O_2{=} \end{array}\right\} C_4H_2O_2;$$

$$\text{Tartar-emetic is } \left.\begin{array}{l} \left.\begin{array}{l} K \\ (SbO) \end{array}\right\rangle{=}O_2{=} \\ H_2{=}O_2{=} \end{array}\right\} C_4H_2O_2.$$

Metallic Triad.

Gold, Au.

225. Gold owes its commercial value not only to its beauty, its density, and its scarcity, but also to its malleability,

which allows it to be beaten into extremely thin leaves, and to its very feeble chemical affinities, by reason of which, it resists the corrosive, tarnishing and solvent agents with which it may come in contact.

◆

CHAPTER IV.

The Tetrads.

The Non-Metallic Tetrads.

(a)	Carbon,	C	12;
(b)	Silicon,	Si	28;
	Titanium,	Ti	50;
	Tin,	Sn	118.

226. These substances resemble each other, mainly in their Oxygen compounds. They all form anhydrides, acids and salts after the same type,

CO_2	Carbonic	anhydride;	H_2CO_3	Carbonic	acid;
SiO_2	Silicic	“	H_2SiO_3	Silicic	“
TiO_2	Titanic	“	H_2TiO_3	Titanic	“
SnO_2	Stannic	“	H_2SnO_3	Stannic	“

227. Carbon is the characteristic element of an enormous number of organic, i. e., animal and vegetable compounds. In a somewhat similar way, Silicon is the characteristic element of a very great number of mineral compounds.

(a) Carbon,

Distribution.

228. In the mineral kingdom, Carbon exists in great abundance. In the three forms of *Coal, Graphite or Plum-*

bago, and the *Diamond*, Carbon is usually *said* to exist in the free state; but although all these substances consist largely of Carbon, they cannot either of them be truly said to be the pure element.

Combined with Oxygen as CO_2 it exists in the atmosphere, in small proportion but in large quantity.

Marbles and limestones are forms of Calcic carbonate, $CaCO_3$.

As has been before remarked, it is the characteristic element of natural and artificial organic compounds. (See p.32).

(i) The Diamond is Carbon crystallized. By burning it in Oxygen, CO_2 is produced, and a small amount of mineral ash is left. The diamond is sometimes colorless and sometimes colored. It is always very hard. If it could be manufactured with its properties as found in nature, it would be of great use in the arts, aside from its value as a gem.

(ii) Charcoal is produced, when organic matters are heated under conditions which do not allow their complete combustion. This heating may be performed in close iron retorts, or in heaps (technically termed *pits*) covered with sods.

Hard coal is found in the earth in immense deposits, which are evidently the remains of a rank vegetation which flourished during an early geological period called the Carboniferous age. There are two principal varieties of coal, called respectively Bituminous and Anthracite coal. The former variety burns with abundant and luminous flame, because it contains a much larger proportion of Hydrogen. When the coal is heated in the fire or in a retort, this Hydrogen is evolved, in combination with a portion of the Carbon, in the form of coal-gas or illuminating-gas, which gas burns with luminous flame. The illuminating-gas is not a substance of definite composition. It is a mixture of a large number of gases.

(iii) Graphite or Plumbago or Black-lead, appears to be a natural product similar to the artificial one called coke. It seems to be a residue from coal which has been subjected to great heat and pressure. It burns with great difficulty.

Properties.

229. Wood charcoal, or better, animal charcoal, has the power of *condensing gases* in its pores. It deödorizes putrefying organic matters by absorbing both the offensive gases, and the Oxygen of the air. The Oxygen slowly oxydizes the offensive gases.

Charcoal has likewise the power, to a remarkable extent, of *absorbing coloring matters.* Thus, bone-black is used in enormous quantities by the sugar refiners for decolorizing the sugar syrups.

Chemically, Carbon is very inert at low temperatures, but at high temperatures it is very active. Its compounds appear to be absolutely numberless.

230. There are two reasons for the great number of the compounds of Carbon. These are,

(a) Its high equivalence—4.

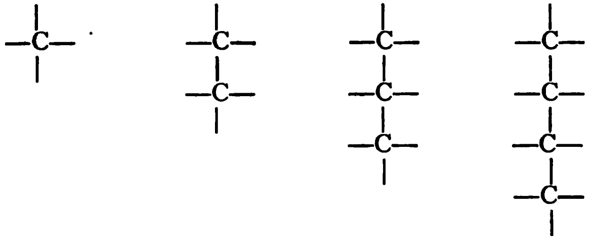
(b) The almost indefinite power of the Carbon atoms *of linking together.* The various ways in which this power manifests itself become apparent from a consideration of the following topics.

Compounds of Carbon with Hydrogen.

231. These compounds are very numerous. They are arranged in about 14 groups called homologous series.

1st Series, The Paraffines, C_nH_{2n+2}.

Plans of structure:



Examples.

Methyl	hydride,	CH_4	or	CH_3—H
Ethyl	"	C_2H_6	"	C_2H_5—H
Propyl	"	C_3H_8	"	C_3H_7—H
Butyl	"	C_4H_{10}	"	C_4H_9—H
Amyl	"	C_5H_{12}	"	C_5H_{11}—H
Hexyl	"	C_6H_{14}	"	C_6H_{13}—H

and so on.

The first three members are gases; the second three members are volatile liquids; but as the series advances, the members become less and less volatile, until at length they become solids. The increase in density is uniform and regular; the rise in boiling point is about 30° C. for each addition of CH_2.

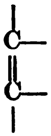
The first member, CH_4, is called marsh-gas, because it is often formed spontaneously by the decomposition of vegetable matter in marshes; it is viewed as containing the radicle Methyl, CH_3, in combination with a fourth atom of Hydrogen.

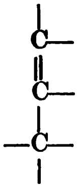
A large number of the higher members are found in American petroleum.

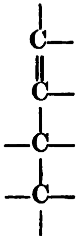
The destructive distillation of coal (in the manufacture of coal-gas) gives rise to many gaseous, liquid, and solid hydrocarbons of this series, as well as of other series.

2d Series, The Olefines, C_nH_{2n}.

The plan of structure of this series is this:







Examples.

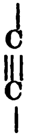
Ethylene	C_2H_4
Propylene	C_3H_6
Butylene	C_4H_8
Amylene	C_5H_{10}
Hexylene	C_6H_{12}
* *	
Cetene	$C_{16}H_{32}$
* *	
Cerotene	$C_{27}H_{54}$
* *	
Melene	$C_{30}H_{60}$

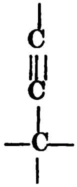
The first member, the hypothetical Methylene, CH_2, appears not to exist, notwithstanding the existence of its Oxygen analogue, Carbonous oxide, CO.

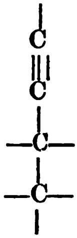
Ethylene is an important and valuable constituent of illuminating-gas.

3d Series, The Acetylenes, C_nH_{2n-2}.

The plan of structure of this series is this:







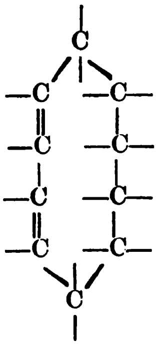
Examples.

Acetylene	C_2H_2
Allylene	C_3H_4
Crotonylene	C_4H_6
Valerylene	C_5H_8

Acetylene is a constituent of coal-gas. It is also interesting from the fact that it may be formed directly, when the voltaic arc flows between two Carbon poles, in an atmosphere of Hydrogen.

4th Series, The Terpenes, C_nH_{2n-4}.

The plan of structure is this:



Examples.

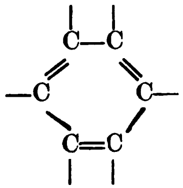
Valylene	C_5H_6
* *	
Turpentine	$C_{10}H_{16}$

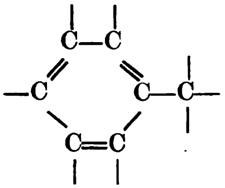
The most important member, is oil or spirits of Turpentine. But many fragrant oils, as oil of Lemons, oil of Oranges, oil of Bergamot, have the same constitution, $C_{10}H_{16}$.

To this same group belong many resins and balsams, as rosin, gum-copal, mastic, caoutchouc, gutta-percha, etc. They are all oxidation products of the Terpenes.

5th Series, The Benzenes, or the Aromatic Series, C_nH_{2n-6}.

The plan of structure is this :





Examples.

Benzene	C_6H_6	or	C_6H_5 —H
Toluene	C_7H_8	"	C_7H_7 —H
Xylene	C_8H_{10}	"	C_8H_9 —H
Cumene	C_9H_{12}	"	C_9H_{11}—H
Cymene	$C_{10}H_{14}$	"	$C_{10}H_{13}$—H
* *			
Amyl-xylene	$C_{13}H_{20}$		

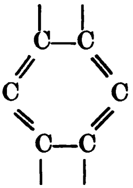
These hydro-carbons are of great interest from the large number of important compounds which are derived from them. Among these derivatives, the aniline colors are the most prominent.

All, except the last member, are obtained from the destructive distillation of bituminous coal, in the manufacture of illuminating gas. The members are liquid and have different boiling points. Hence, they are separable by fractional distillation.

The most important, commercially, are Benzene, or Benzol or Phenyl hydride, $C_6H_5—H$; and Toluene, or Toluol or Tolyl hydride, $C_7H_7—H$.

6th Series, The Phenylene Series, C_nH_{2n-8}.

The plan of structure is this :



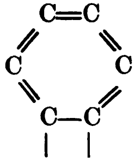
Examples.

The only known members are,

	Phenylene	C_6H_4
and	Cinnamine or Styrolene	C_8H_8

7th Series, ————————, C_nH_{2n-10}.

Hypothetical plan of structure :

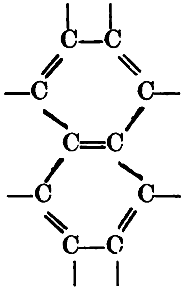


Example.

Dehydrated Cholesterin ($C_{26}H_{44}O$) $C_{26}H_{42}$

8th Series, Naphthalene, C_nH_{2n-12}.

The plan of structure is this:



Example.

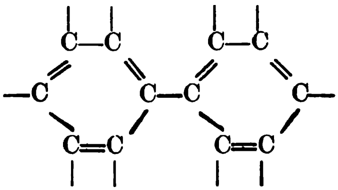
Naphthalene $C_{10}H_8$

This is the only member known.

It is one of the constituents of coal tar. It gives rise to a series of coloring matters, which closely correspond in structure with the aniline colors. The former have the radicle Naphthyl, $C_{10}H_7$, where the latter have the radicle Phenyl, C_6H_5.

9th Series, ————, C_nH_{2n-14}.

The plan of structure is this:



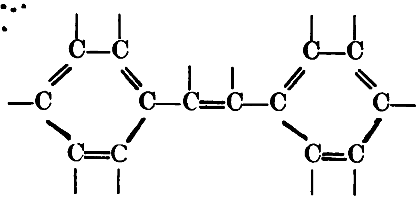
Examples.

Only two members are known:

Di-phenyl	$C_{12}H_{10}$
Di-benzyl	$C_{14}H_{14}$

10th Series, Stilbene, C_nH_{2n-16}.

The plan of structure is this:



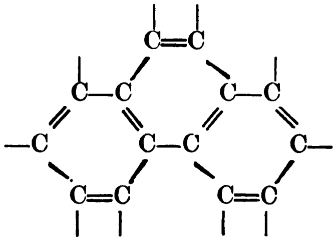
Example.

Only one member is known.

Stilbene $C_{14}H_{12}$

11th Series, Anthracene, C_nH_{2n-18}.

The plan of structure is this:



Example.

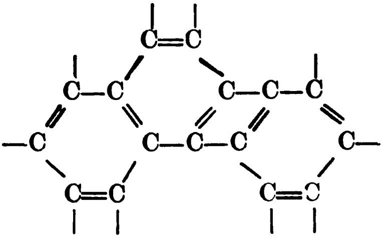
Anthracene, $C_{14}H_{10}$

This substance is a white solid produced by the distillation of wood, bituminous coal, etc. It is usually obtained from the coal-tar of gas-works. It has suddenly sprung into great commercial importance, since 1859, when Graebe and Liebermann discovered that it could be oxidized into Alizarine, $C_{14}H_8O_4$, the most valuable coloring matter of the Madder root.

The 12th Series seems to be Wanting.

13th Series, Pyrene, C_nH_{2n-22}.

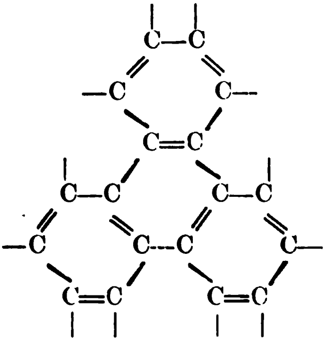
The plan of structure is this :



Example.
Pyrene $C_{16}H_{10}$

14th Series, Chrysene, C_nH_{2n-24}.

The plan of structure is this:



Example.
Chrysene, $C_{18}H_{12}$

The members of these last two series are also found in coal-tar.

Illuminating-gas.

232. In manufacturing coal-gas, bituminous coal is heated in retorts of earthen-ware or of iron. Under the influence of the high temperature, a complicated series of molecular rearrangements takes place. The coal contains Carbon, Hy-

drogen, Oxygen, Nitrogen and Sulphur, besides some mineral matters. These elements form a great variety of new combinations among themselves.

Moreover, there are three classes of products formed; those which at the ordinary temperature of the air are solid; those which are liquid; those which are gaseous.

(i) *The solids* are *coke and gas-carbon.* The coke contains about 95 per cent. of Carbon and about 5 per cent. of mineral matters. It is readily combustible and is used as fuel.

The gas-carbon is a very compact form of Carbon which slowly accumulates as a coating upon the interior of the retort. It is removed only with great difficulty.

(ii) *The liquids* are *tar*, *light-oil*, and *ammoniacal-liquor.* The volatile products from the retorts, pass first into *the hydraulic main*, a horizontal tube, half full of water. This water absorbs the Ammonium salts e. g. Ammonic carbonate $(NH_4)_2CO_3$ and Ammonic sulphide $(NH_4)_2S$ with traces of Ammonic chloride, NH_4Cl, Ammonic cyanide, NH_4Cy, and Ammonic sulpho-cyanate, NH_4SCy. At the same time it condenses certain vapors to a thick tarry product. But the hydraulic main is necessarily at a high temperature. The gas is therefore subjected next to a cooling, in large upright chambers or pipes called condensers. Here it deposits more tarry liquids, the gas itself passing on to the purifiers.

The tarry products are very complex. They contain:

- Liquids,
  - Propyl,
  - Butyl,

  - Benzene,
  - Toluene,
  - Xylene,
  - Cumene,
  - Cymene, etc.,

Solids,	Naphthalene,	
	Anthracene,	
	Pyrene,	
	Chrysene, etc.,	
Acids,	Carbolic acid (Phenyl alcohol)	$C_6H_5—O—H$
	Cresylic acid,	$C_7H_7—O—H$
	Rosolic acid,	$C_{20}H_{16}O_3$
Amines,	about a dozen, including	
	Phenyl-amine (aniline),	$C_6H_5—N=H_2$

(iii) The *gases* may be divided into three classes, as follows:

Those of greater value,	Propyl,	C_3H_7
	Butyl,	C_4H_9
	Ethylene,	C_2H_4
	Propylene,	C_3H_6
	Butylene,	C_4H_8
	Acetylene,	C_2H_2
	Benzene,	C_6H_6
	Naphthalene,	$C_{10}H_8$
Those of lesser value,	Marsh gas,	CH_4
	Hydrogen,	H
	Carbonous oxide,	CO
Those that are injurious,	Carbonic oxide,	CO_2
	Carbonic sulphide,	CS_2
	Cyanogen,	Cy (CN)
	Sulpho-cyanogen,	CyS
	Sulphydric acid,	H_2S
	Ammonia gas,	H_3N
	Nitrogen,	N

The gases are passed through purifiers for the purpose of removing the injurious gases (except the Nitrogen). The *scrubber* is a chamber in which small jets of water come in contact with the gases. It absorbs portions of all of the injurious gases. A large portion of what still remains is finally absorbed by passing through large chests containing trays of quick-lime. In place of quick-lime, Ferric hydrate, $Fe_2O_6H_6$ is now often used.

Compounds of Carbon with Oxygen.

233. These are two, Carbonous oxide, CO,
Carbonic oxide, CO_2.

Carbonous Oxide, CO.

234. This is a colorless gas.

It is combustible and burns with a blue flame, forming CO_2. It is given out by coal fires when they have a very large supply of coal and a very small supply of Oxygen.

When taken into the lungs and thence into the blood, it is very poisonous.

Carbonic Oxide or Carbonic Anhydride, CO_2.

235. This is the sole product of the combustion of pure Carbon in an *excess* of Oxygen.

It is evolved in animal respiration, and in the combustion of wood, coal, and Carbon compounds.

It is evolved during the heating of limestones in lime-kilns.

$$CaCO_3 \text{ heated} = CaO + CO_2$$

It is oftenest prepared by the action of acid upon marble, ($CaCO_3$).

$$CaCO_3 + 2HCl = CaCl_2 + CO_2 + H_2O$$

Properties.

236. At ordinary temperatures it is a colorless gas; but by means of cold and pressure it may be condensed to a colorless liquid and even to a snowy solid.

Its molecular weight is 44 and its density 22, (density of air, 14.45).

It does not support animal respiration; moreover, when breathed in the pure state, it produces a spasmodic closing of the glottis, so as to kill the animal by suffocation.

But though it is injurious when the attempt is made to take it into the lungs, it is not at all so when taken into the stomach. Most cooling beverages like soda-water, effervesce because of the escape of Carbonic anhydride, which by pressure and low temperature dissolves readily in water to form Carbonic acid, H_2CO_3.

Carbonic anhydride neither burns nor supports the combustion of other substances.

Carbonic anhydride is absorbed by living vegetable organisms; the Oxygen is evolved, while the Carbon is *fixed* in the structure of the organism.

Compound of Carbon with Sulphur.

237. With Sulphur, Carbon forms Carbonic di-sulphide, CS_2. It is a very volatile and combustible liquid.

Compound of Carbon with Nitrogen.

238. With Nitrogen, Carbon forms Cyanogen, CN or Cy or molecularly expressed, CN—CN.

Cyanogen is a gas which acts much like Chlorine, in that it is a monad, and forms HCy, KCy, AgCy, etc., called respectively Cyanohydric acid, Potassic cyanide, Argentic cyanide, etc.

Cyanogen is also a constituent of a very large number of complex metallic salts.

Complex Carbon Compounds.

239. The following series of types includes from 95 to 99 per cent. of the Carbon compounds :

1st Type, H—H. The Hydrogen-gas Type.

The general formula is $\overset{\pm}{R}$—$\overset{\pm}{R}$.

$\overset{+}{R}$ represents one molecule of an electro-positive radicle. It may be either simple or compound. When compound, it is usually made up of Carbon and Hydrogen.

$\overline{R}$ represents one molecule of an electro-negative radicle. It may be either simple or compound. When compound, it it is usually made up of Carbon, Hydrogen and Oxygen.

Examples.

$\overset{+}{R}$—$\overset{+}{R}$	**Positive radicle**	CH_3—CH_3	**Methyl,**
$\overline{R}$—$\overline{R}$	**Negative radicle**	C_2H_3O—C_2H_3O	**Acetyl,**
$\overset{+}{R}$—H	**Hydride**	CH_3—H	**Methyl hydride (marsh-gas),**
$\overline{R}$—H	**Aldehyd**	C_2H_3O—H	**Acetic aldehyd,**
$\overset{+}{R}$—Cl	**Haloid ether**	C_2H_5—Cl	**Ethyl-Chlorhydric-ether or Ethyl-chloride,**
$\overline{R}$—Cl	**Acid halide**	C_2H_3O—Cl	**Acetyl-chloride.**

2d Type, H_2O, or H—O—H, The Water Type.

The general formula is $\overset{\pm}{R}$—D—$\overset{\pm}{R}$. D, represents one atom of a linking dyad. It is usually Oxygen.

M, represents one atom of a monad metal.

Examples.

$\overset{+}{R}$—O—$\overset{+}{R}$	**Simple ether**	C_2H_5—O—C_2H_5	**Ethylic ether,**
$\overset{+}{R}$—O—$\overset{+}{R}$	**Mixed ether**	CH_3—O—C_2H_5	**Methyl-ethyl ether**
$\overline{R}$—O—$\overline{R}$	**Anhydride**	C_2H_3O—O—C_2H_3O	**Acetic anhydride,**
$\overset{+}{R}$—O—$\overline{R}$	**Compound ether**	C_2H_5—O—C_2H_3O	**Ethyl-acetic ether,**
$\overset{+}{R}$—O—H	**Alcohol**	C_2H_5—O—H	**Ethyl alcohol,**
$\overset{+}{R}$—S—H	**Mercaptan**	C_2H_5—S—H	**Ethyl sulpho-hydrate,**
$\overset{+}{R}$—Se—H	**Seleno-mercaptan**	C_2H_5—Se—H	**Ethyl seleno-hydrate,**
H—O—$\overline{R}$	**Acid**	H—O—C_2H_3O	**Acetic acid,**
M—O—$\overline{R}$	**Salt**	Na—O—C_2H_3O	**Sodic acetate.**

3d Type, H_3N, The Ammonia-gas Type.

Examples.

$\overset{+}{R}-N=H_2$ Amine, $C_2H_5-N=H_2$ Ethyl-amine,
$\overset{+}{R}-As=H_2$ Arsine, $(CH_3)_3$ As Tri-methyl-arsine,
$\overset{+}{R}-Sb=H_2$ Stibine, $(C_2H_5)_3$ Sb Tri-ethyl-stibene,
$\overset{+}{R}-P=H_2$ Phosphine, $C_2H_5-P=H_2$ Ethyl-phosphine,

$\overline{R}-N=H_2$ Amide $C_2H_3O-N=H_2$ Acet-amide,
$\overset{+}{R}-N\begin{smallmatrix}-\overline{R}\\-H\end{smallmatrix}$ Alkalamide, $C_2H_5-N\begin{smallmatrix}-C_2H_3O\\-H\end{smallmatrix}$ Ethyl-acet-amide,
$\overline{R}''\begin{smallmatrix}-O-H\\-N=H_2\end{smallmatrix}$ Amic acid, $(C_4H_4O_2)''\begin{smallmatrix}-O-H\\-N=H_2\end{smallmatrix}$ Succin-amic acid.

4th Type, H_4C, The Marsh-gas Type.

Example.

$O=C=\overset{+}{R}\overset{+}{R}$ Ketone, $O=C=(CH_3)_2$ Ordinary acetone (methyl-acetyl)

5th Type, NH_4Cl, Ammonium-chloride Type.

Examples.

$\overset{+}{R}_4\equiv\overset{v}{N}-Cl$ Ammonium subs.comps. $(C_2H_5)_4\equiv N-Cl$ Ethyl-ammonium chloride,
$\overset{+}{R}_4\equiv\overset{v}{P}-Cl$ Phosphonium subs.comps. $(CH_3)_4\equiv P-Cl$ Tetra-methyl phosphonium chloride.
$\overset{+}{R}_4\equiv\overset{v}{As}-Cl$ Arsonium substitution compounds.
$\overset{+}{R}_4\equiv\overset{v}{Sb}-Cl$ Stibonium substitution compounds.

6th Type, Organo-metallic Bodies.

Examples.

$\overset{+}{R}_2=Zn$ $(C_2H_5)_2$ Zn Zinc ethide
$\overset{+}{R}_4\equiv Sn$ $(C_2H_5)_4$ Sn Stannic tetr-ethide.

The Fitness of Carbon for use as Fuel.

238. This fitness depends upon a great number of facts, but mainly upon these:

(a) Immense supplies of unburned Carbon, as coal, are found just below the surface of the earth.

(b) The atmosphere contains an abundant supply of Oxygen.

(c) Carbon is infusible, and so does not clog the draft.

(d) *The product of its combustion in air* is gaseous; it is of the same volume as the Oxygen used in forming it; it is non-corrosive; it is advantageously withdrawn from the air by vegetation, and so does not unduly accumulate.

Silicon, Si.

239. Silicon occurs in the earth in great abundance; while Oxygen forms, by weight, one-half of the earth, Silicon forms one-fourth.

Silicon is never found free in nature. Combined with Oxygen it forms Silicic anhydride, SiO_2. (By weight, 28 parts Si with 32 parts O). Silicic anhydride combines with water to form Silicic acid, H_2SiO_3, H_4SiO_4, etc. With the metals, it forms a very great variety of metallic silicates.

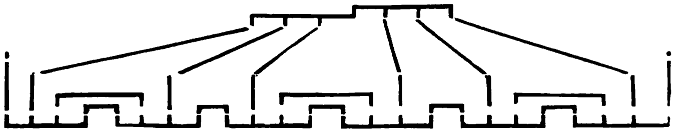
240. Silicic anhydride is also called Silica. Its most common form on the surface of the earth, is ordinary sand. It also forms three other tolerably distinct varieties of minerals, the *vitreous* variety, of which rock-crystal or quartz is an example; the *chalcedonic* variety of which agate is an example; the *jaspery* variety, of which bloodstone is an example.

241. With Fluorine, Silicon forms a gaseous compound, Silicic fluoride, $SiFl_4$.

242. The mineral silicates are very numerous and very complicated in structure. Their style of composition may be illustrated by the Feldspars. Feldspar is an abundant mineral, existing in three principal varieties, viz.:

(a) Ordinary. Feldspar, *Orthoclase*, Potash Feldspar, K_2O, Al_2O_3 $(SiO_2)_6$.

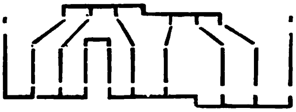
$$\left.\begin{matrix}K_2\\Al_2\end{matrix}\right\}O_8\left\{Si_6O_8\right.$$



(b) *Albite*, Soda Feldspar Na_2O, Al_2O_3 $(SiO_2)_6$.
(Diagram, like orthoclase).

(c) *Labradorite*, Lime Feldspar $[Na_2O,CaO,Al_2O_3]$, Si_3O_6

$$\left.\begin{matrix}Na_2\\Ca\\Al_2\end{matrix}\right\}O_{10}\left\{Si_3\right.$$



APPENDIX.

TABLES.

TABLE I.—ENGLISH MEASURES.

Troy Weight.

Pound.	*Ounces.*	*Pennyweights.*	*Grains.*		*French Grammes.*
1	12	240	5760	=	373.2419
	1	20	480	=	31.1035
		1	24	=	1.5552

Apothecaries' Weight.

℔ *Pound.*	℥ *Ounces.*	ʒ *Drachms.*	℈ *Scruples.*	gr *Grains.*		*French Grammes.*
1	12	96	288	5760	=	373.2419
	1	8	24	480	=	31.1035
		1	3	60	=	3.8879
			1	20	=	1.2959
				1	=	.0648

Avoirdupois Weight.

Pounds.	*Ounces.*	*Drachms.*	*Grains.*		*French Grammes.*
1	16	256	7000	=	453.5926
	1	16	437.5	=	28.3495
		1	27.343	=	1.7718

TABLE II.—METRIC MEASURES.

Measures of Length.

1 Millimetre = 0.001 of a metre
1 Centimetre = 0.010 of a metre
1 Decimetre = 0.100 of a metre = about 4 inches.
1 Metre = 1.000 Metre = 39.37inches.
1 Decametre = 10.000 metres
1 Hectometre = 100.000 metres
1 Kilometre = 1000.000 metres = about ⅝ of a mile.
1 Myriametre = 10,000.000 metres = about 6⅕ miles.

Measures of Surface.

1 Centiare = 1 Square metre = about 1⅕ square yards.
1 Are = 100 Square metres.
1 Hectare = 10,000 Square metres= about 2½ acres.

Measures of Volume.

1 Cubic metre = 1000 Cubic decimetres
= 1000 Litres, or one Kilolitre.
= 1 Stére

Measures of Capacity.

1 Litre = { 1 Cubic decimetre or 1000 cubic centimetres } = **about 1 quart.**

Measures of Weight.

1 Milligramme = 0.001 of a gramme = about 1/65 of a grain.
1 Centigramme = 0.010 of a gramme
1 Decigramme = 0.100 of a gramme
1 Gramme = 1.000 Gramme = about 15½ grains.
1 Decagramme = 10.000 grammes
1 Hectogramme = 100.000 grammes
1 Kilo (gramme) =1000.000 grammes = about 2⅕ lbs.

1 Tonneau =1000. Kilo's = about 1 Ton.

TABLE III.—MINIATURE DICTIONARY OF WEIGHTS AND MEASURES.

1	Are, = 100 sq. metres	119.6	sq. yds.
1	Centiare, = 1 sq. metre = 100 sq. centimetres	1550.	sq. inches.
1	Centimetre, = $\frac{1}{100}$ of a metre	.3937	inches.
1	Cubic centimetre; (of dist. water, weighs 1 Gm.) =	.0610	cub. in.
1	Cubic decimetre, (same as 1 Litre	1000	C. C.).
1	" " of dist. water, weighs 1000 Gms., or	1.	Kilo.
1	" " = *in English* or Imperial measure	.8804	quarts.
1	" " *in American* or Wine measure,	1.0567	quarts.
1	Cubic foot, (1728 cub. in.)	28,315.3119	cub. cent.
1	" of water (at 62° F.) weighs	62.3210	lbs Av.
1	Cubic inch	16.3861	cub. cent.
1	" of water (at 62° F.) weighs	252.458	grains.
1	" of water (at 60° F.) weighs	252.5	"
1	Cubic metre, (1 Stére) 1,000,000. c.c. or	1000.	Litres.
1	Fluid ounce, Imperial, = 28.4 c.c.	1.7329	cubic in.
1	" Wine meas. = 29.5 c.c.	1.8047	"
1	" Imperial, of water (62° F.) weighs	437.5	grains.
1	" Wine meas. of water (60° F.) weighs	455.7	"
1	Foot,	30.48	centimetres.
1	Gallon, Imperial, 277.274 cub. inches	4.5435	Litres.
1	" " of water, weighs (62° F.) 10 lbs. or	70,000.	grains.
1	Gallon Wine measure, 231. cub. in.	3.7852	Litres.
1	" " of water, weighs (60° F.) 8.33 lbs or	58,372.2	grs.
1	Gramme (1 c.c. of dist. water, 4° C.)	15.4323	grains
1	Inch,	2.54	centimetres.
1	Kilogramme, (1000 Grammes,)	2.2046	lbs. Av.
1	Litre (see cubic Decimetre,)		
1	Metre, (1 40-millionth of Earth's meridian,)	39.3708	inches.
1	" equals about 3 ft. 3 in. $\frac{3}{8}$ in.		
1	Pint, W.,=16 fl oz. = of water, 60° F., 7291.2 gr.	473.148	cub. cent.
1	" Imp.=20 " " 62° F., 8750. gr.	567.932	cub. cent.
1	Quart, Wine, 32 fl. oz.	.9463	litres.
1	" Imp., 40 "	1.1358	litres.
1	Ton Avoirdupois, (2000 lbs.)	29166$\frac{2}{3}$.	oz. Troy.
1	Tonneau, 1 million gms.	1000	Kilo's.

TABLE IV.—The Equivalences of Elements and their Atomic Weights.

Hydrogen is the standard; it is a monad, and its Atomic weight is 1.

NON-METALS.

Monads.	Dyads.	Triads	Tetrads.
		N 14	
Fl 19	O 16	Bo 11	C 12
Cl 35.46	S 32	P 31	Si 28
Br 80	Se 79.4	As 75	Ti 50
I 127	Te 128	Sb 122	Sn 118

METALS.

Monads.	Dyads.	Triads.	Tetrads.
Ag 107.97	Pb 207	Bi 208	
K 39.11	Ba 137	Au 196.	Pt 197.88
Na 23.	Sr 87.5		
Li 7.	Ca 40		
	Hg 200		
	Cu 63.4		
	Co 59		
	Ni 59		
	Fe 56		
	Mn 55		
	Cr 52.48		
	Al $\frac{55}{2}$		
	Zn 65		
	Mg 24		

TABLE V.—A List of Acids

and some other Hydrogen Compounds.

HALOID ACIDS.		NOT ACIDS.	
Monad.	Dyad.	Triad.	Tetrad.
HFl	H_2O	H_3N	H_4C
HCl	H_2S	H_3P	
HBr	H_2Se	H_3As	
HI	H_2Te	H_3Sb	
HCy			

TERNARY ACIDS.

I-III-V-VII	IV or VI or VIII	III or V	IV
$HClO$	H_2SO_3	HNO_2	H_2CO_3
$HClO_2$	H_2SO_4	HNO_3	H_2SiO_3
$HClO_3$			H_2TiO_3
$HClO_4$	H_2SeO_3	$HSbO_2$	H_2SnO_3
	H_2SeO_4	$HSbO_3$	
	H_2TeO_3	H_3PO_3	
	H_2TeO_4	H_3PO_4	
	H_2MnO_4	H_3AsO	
	$H_2Mn_2O_8$	H_3AsO_4	
	H_2CrO_4	H_3BO_3	

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